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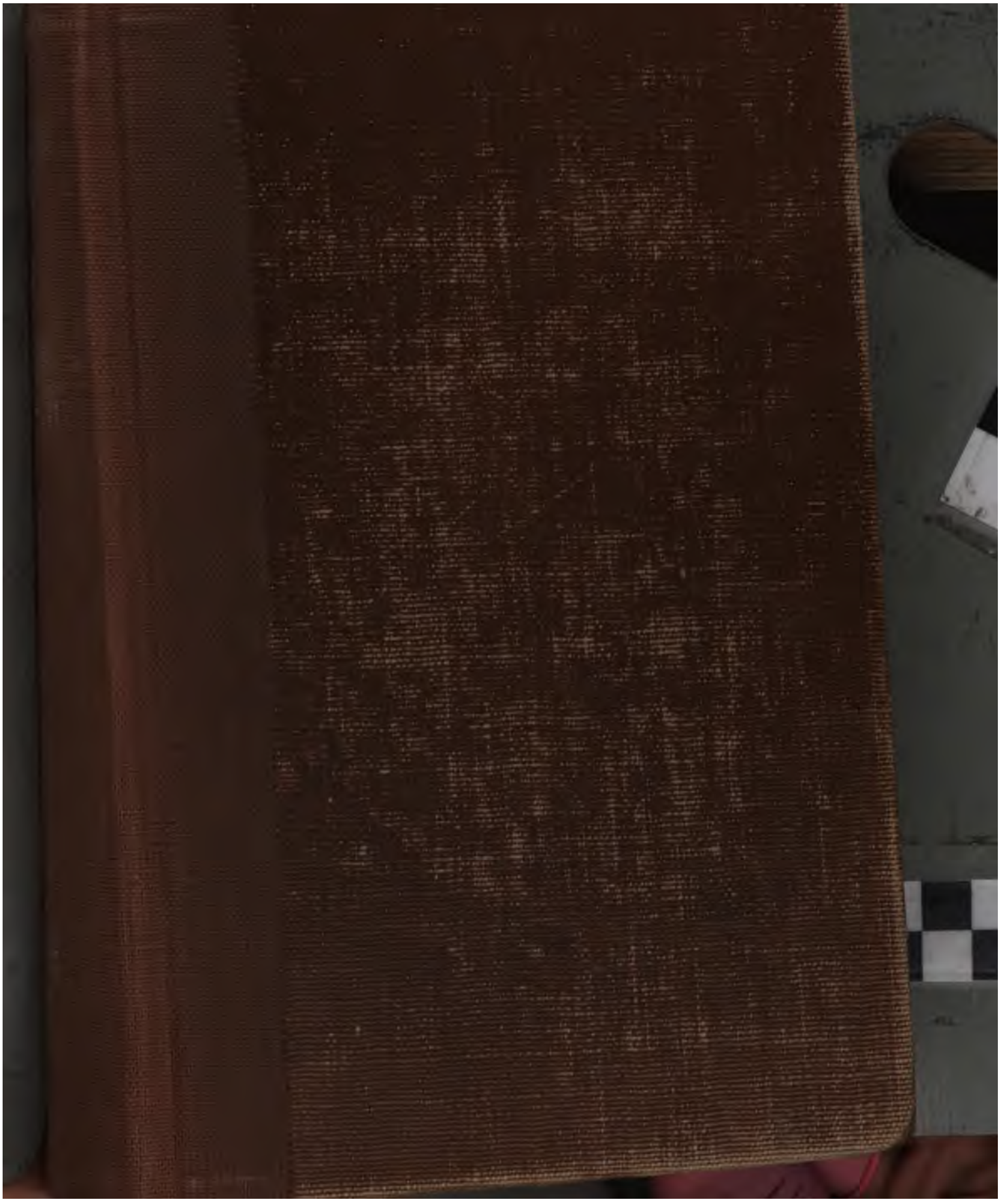

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BULLETIN 397

MINERAL DEPOSITS

OF THE

CERBAT RANGE, BLACK MOUNTAINS, AND GRAND WASH CLIFFS

MOHAVE COUNTY, ARIZONA

BY

F. C. SCHRADER

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MINERAL DEPOSITS OF THE CERBAT RANGE, BLACK MOUNTAINS, AND GRAND WASH CLIFFS, MOHAVE COUNTY, ARIZONA.

By F. C. SCHRADER.

INTRODUCTION.

FIELD WORK AND ACKNOWLEDGMENTS.

The field work forming the basis of this paper is a reconnaissance made by the writer, under the direction of Mr. Waldemar Lindgren, during the period extending from October, 1906, to February, 1907. The purpose of the paper is to furnish a general idea of the character, occurrence, distribution, and development of the mineral resources of a part of western Arizona (see fig. 1) concerning which little has hitherto been known. The reconnaissance covered almost the whole of Mohave County, except some smaller camps in the extreme north and in the southern part of the county, which could not be reached in the time allotted to the work.

Owing to the desert conditions of the region—the scarcity of grass and water—a camp outfit was dispensed with and subsistence was obtained from the mining camps and prospectors.

The general method of work employed was to make hasty sketch maps and sections of the various camps or mines, using a box compass and aneroid for determination of bearings and elevations, and tying the work wherever practicable to Land Office section or township corners, railroads, other surveys, and mining-claim monuments.

The early reconnaissance maps of the Geological Survey, especially the Camp Mohave and Diamond Creek contour sheets, though for the most part too crude for local use, were found to be of material service in general. In a broad sense they represent fairly well the physical features of the region and are used as the base of the geologic map (Pl. I) in the present report.

Wherever available, the geology of portions of the area not visited by the writer has been compiled from the maps and reports of the

earlier surveys, notably those of Newberry, Gilbert, Marvine, and Howell, and the later ones of Lee and Ransome, of which a fuller account appears on subsequent pages.

To the various mining companies, prospectors, and mining men throughout the field grateful acknowledgments are due for courtesies, hospitality, transportation, and other assistance, which was extended

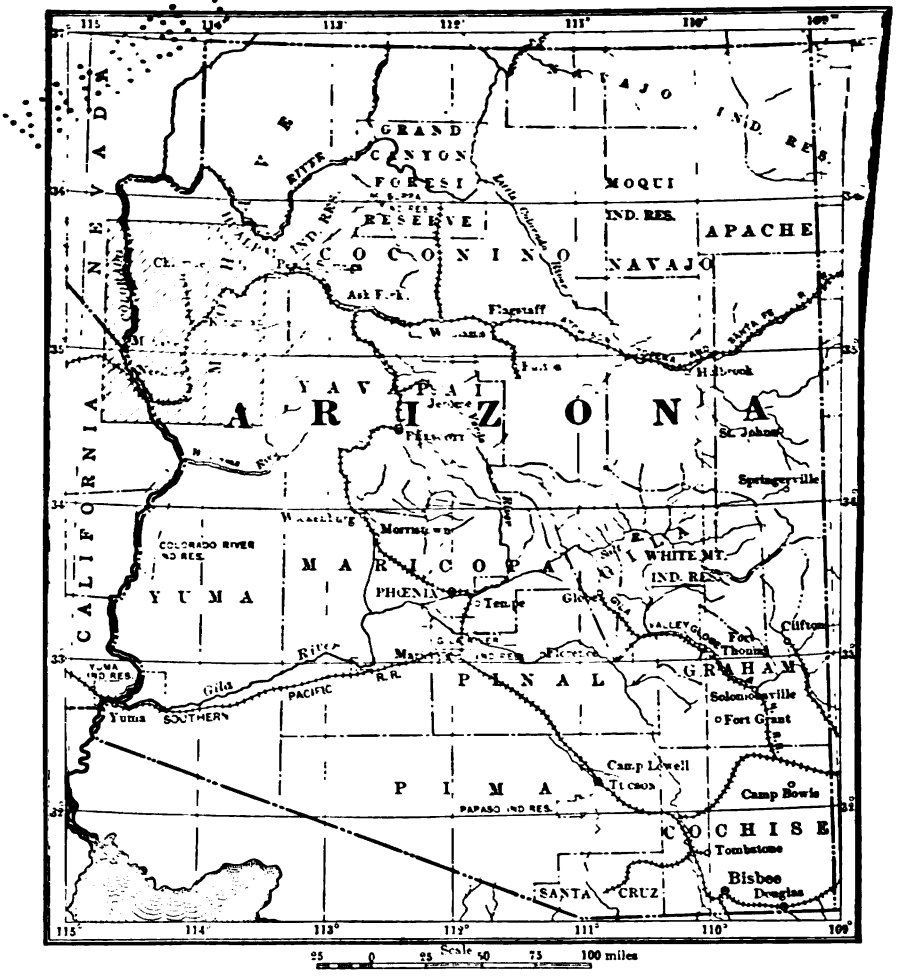

FIGURE 1.—Index map showing position of area covered in this report.

with unusual generosity. Especially important aid was received from the companies in the Gold Road, Silver Creek, Pyramid, Mocking Bird, Stockton Hills, Cerbat, Chloride, Gold Basin, and Music Mountain districts.

Among the individuals to whom the writer wishes to express his sincere thanks for assistance rendered are superintendents S. R.

Porter, J. W. Moore, O. F. Kuencer, C. V. Turner, W. C. Howard, F. L. Garrison, W. H. Cushing, Leonard Hoffman, H. L. McCarn, and J. D. Jordan, and Messrs. Daniel Bosqui, Levi Suthers, J. de Sallmarde, A. M. McDuffee, Robert Brannack, C. J. Hutchinson, C. J. Rhodes, George Aitken, John Barry, A. W. Braettlund, Daniel McFarland, Thomas Patterson, C. E. Heimer, and R. C. Jacobs. In the office the microscopic determinations of the rock and ore sections were made by Mr. Lindgren and Mr. B. S. Butler, and the chemical analyses by Messrs. George Steiger and E. C. Sullivan.

PREVIOUS WORK.

Probably no other region in the United States of equal importance in respect to mineral resources has received so little attention as western Arizona. No official report has treated the mining geology of this area, though its general geologic and geographic features have been known for some time through the earlier explorations. In 1853–54 Jules Marcou, as geologist of the Pacific Railroad route expedition, visited the southeast corner of the area, and his notes, published in the reports of the expedition,[a] include a preliminary description and map of the geology of this section. In a later work[b] the same author, referring to the same region, gave the principal formations composing the Cerbat Mountains, and showed on his geologic map of North America the geology of the entire region, but only in the most general manner.

A more complete account of the region was later given by Newberry, who, as geologist with the Ives expedition[c] in 1857–58, ascended Colorado River to the mouth of the Virgin and later traversed the area in a northeasterly direction from Camp Mohave, on the Colorado, to Music Mountain, at the edge of the Colorado Plateau. He very ably describes the geology and geography of the country along his route of travel, and includes in his description some notes on the mineral deposits of the Cerbat Range.

Further contributions on the mineral deposits of this region were later published by Silliman, who, entering from the west by way of Camp Mohave, visited the Silver Creek and other regions in the San Francisco mining district in 1864.[d]

In 1871 to 1873 the northern and eastern portions of the area were visited and mapped by Gilbert, Marvine, and Howell, geologists with the Wheeler Survey.[e]

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[a] Pacific Railroad Reports, vol. 3, 1856, pp. 156–158.

[b] Marcou, Jules, Geology of North America, 1858, p. 24.

[c] Newberry, J. S., in Lieut. J. C. Ives's report on the Colorado River of the West, 1861, pt. 3, pp. 29–54.

[d] Silliman, Benjamin, jr., On some of the mining districts of Arizona: Am. Jour. Sci. 2d ser., vol. 41, 1866, pp. 289–308.

[e] U. S. Geog. Surveys W. 100th Mer., vol. 3, pts. 1, 2, 3, and 5, and atlas sheets 66, 67, and 75.

In 1900 Comstock, whose experience with the mines and veins of Arizona and adjoining regions had been extensive, published a paper[a] in which he sketched the stratigraphy and mineral deposits of Arizona, presented a sketch map showing three systems of structure lines related to ore deposits, and cited portions of the Cerbat Range in discussing the persistence of his so-called latitudinal gold belts of the primary uplift.

About 1902 detailed topographic work by the Reclamation Service on the lower part of the Colorado was extended northward to a point above Round Island, at about the middle of the western edge of the area here discussed.

During the seasons of 1903 and 1904 a more complete geologic reconnaissance of the area than that of the Wheeler Survey was made by W. T. Lee,[b] who traversed the area in various directions, mapped the geology, and made a collection of igneous rocks that have been determined by Albert Johannsen.

More recently, in 1906, F. L. Ransome made a reconnaissance of the mineral deposits and mines of the Searchlight and Eldorado districts[c] in southern Nevada, bordering the Mohave area on the west, and, in connection with his report on the mines and formations, published a sketch map of the districts, a part of which has been used in the present report.

GEOGRAPHIC RELATIONS.

LOCATION.

The region herein described lies in the western part of Mohave County, Ariz., bordering California and Nevada on the west and north. (See Pl. I, in pocket.) It extends from the thirty-sixth parallel near the Big Bend of Colorado River, on the north, to the south end of the Black Mountains, near latitude 34° 40′, on the south, and from Hackberry and the Grand Wash Cliffs at the edge of the Colorado Plateau, near the 113° 30′ meridian, on the east, to Colorado River, near longitude 114° 45′, on the west. Its longer diameter trends north and south, in which direction it has an extent of about 95 miles; its width is about 75 miles and its area about 7,100 square miles.

The region is composed of naked desert ranges of mountains and broad, desolate, detritus-filled valleys, the southern extension of the topography of the Great Basin. It is best reached by way of the Atchison, Topeka and Santa Fe Railway, the only railroad line traversing it. Near Seligman the railroad begins to descend rapidly

[a] Comstock, Theodore B., Geology and vein phenomena of Arizona: Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 1038–1102.

[b] Lee, W. T., Geologic reconnaissance of a part of western Arizona: Bull. U. S. Geol. Survey No. 352, 1908. Mr. Lee kindly gave the present writer access to his unpublished maps.

[c] Ransome, F. L., Bull. U. S. Geol. Survey No. 303, 1907, pp. 63–79.

to the southwest. Passing through picturesque canyons and washes, in the course of 60 miles it descends 2,000 feet to Hackberry, at the eastern edge of the area described. Picking its grade by detours around the mountains, the railroad continues its descent to Mellen, in the southwestern part of the area, where it crosses Colorado River at an elevation of 500 feet, or about 5,000 feet below its position on the edge of the plateau at Seligman. Near the middle of its course across the area it passes through a gap in the Cerbat Range, a partial break of erosion known to the early explorers as "Railroad Pass." Near its middle this pass widens into a sort of basin in which is situated Kingman, the county seat of Mohave County and the metropolis and distributing point for nearly all the mining regions of northwestern Arizona. Kingman is reached in thirteen hours from Los Angeles.

CLIMATE AND VEGETATION.

The climate of the region is arid, with hot summers and mild winters. The temperature of June, July, and August averages high, but the intensity of the heat is mollified by the dryness of the atmosphere, a more or less constant breeze, and cool nights. The hottest belt follows Colorado River. The climate ranks among the most healthful in the United States.

The annual precipitation, according to E. C. Murphy, of the United States Geological Survey, is about 5 inches—very much less than the evaporation. During hot weather it is largely concentrated in cloud-bursts, and the country is subject to sudden and violent winds, which in the valleys are often accompanied by sand storms. Most of the mountains as well as the valleys are free of snow during winter, and the highest mountains become free of it in early summer.

Portions of the Hualpai Mountains are forested with timber and contain areas of excellent pine suitable for lumbering and mining purposes, and there are a few open groves of scrub piñon or cedar, such as occur at Mineral Park, but otherwise the area is timberless. The vegetation is of the desert type and is confined mostly to the valleys, mesas, and lower slopes of the mountains. It consists mainly of cacti, greasewood, yuccas, soapweed, sage, and cat-tails. The tree yucca (*Y. arborescens*), or "joshua tree," grows in open groves in portions of the White Hills, and during the activity in the White Hills and Gold Basin camps it supplied the fuel used in operating the hoists. Many species of cactus are represented, but the *Sahuaro*, or giant cactus, so common in southern Arizona, does not appear. The branching prickly pear, attaining a height of 4 or 5 feet, is abundant in the Hualpai and Detrital-Sacramento valleys, as is also the greasewood or creosote brush.

White sage is present throughout the area. Grass is usually of scanty growth, but burros live on it, in connection with sagebrush,

the year round, and a few horses and cattle are kept in the Hualpai and Detrital-Sacramento valleys, where also a small amount of wheat and other cereals is grown. On some of the irrigable bottom land along the Colorado, notably in the southwestern part of the area, six crops of alfalfa a year are reported to be raised. The greater part of the Hualpai and Detrital-Sacramento valleys, if supplied with water for irrigation, would also prove excellent for agriculture.

SETTLEMENT AND MEANS OF COMMUNICATION.

The principal settlements, whose locations are shown on the accompanying map, are Kingman, with a population of about 1,000; Chloride, with 500; Goldroad, with 300; and Hackberry, with 200. In respect to churches, mail privileges, newspapers, mercantile and other business houses, fraternal orders, schools, telegraph and cable service, and other social and business facilities, these places compare favorably with any others of their size. The population consists essentially of enterprising, law-abiding Americans and includes representatives from nearly every State in the Union.

Chloride, situated at the terminus of the Arizona and Utah Railroad, about 20 miles north of Kingman, where it connects with the main line of the Atchison, Topeka and Santa Fe Railway, is the subdistributing point for the camps in the northwestern part of the area, and even as far as Eldorado Canyon, Nevada. Hackberry, about 30 miles east of Kingman, on the main line of the Santa Fe, is the distributing point for camps in the eastern part of the area, including Lost Basin, Gold Basin, and Music Mountain.

The settlements and camps are nearly all connected by wagon road, stage line, mail, and telephone, with their distributing points and Kingman, and most of them with one another. The distances of the more important camps from their distributing points are as follows:

Distances of the more important camps from their distributing points.

From Kingman to—	Miles.	From Kingman to—	Miles.
Stockton Hill	11	Pyramid	36
C. O. D. mine	16	Hardyville	30
Gold Road	24	Fort Mohave	44
Vivian via Gold Road	28	From Chloride to—	
Silver Creek via Gold Road	28	Mineral Park	6
Todd Basin	16	Todd Basin	12
Cerbat	14	Cerbat	14
Layne Springs	17	White Hills	23
Mineral Park	20	Eldorado Canyon, Nev.	49
Chloride	26	Virginia Camp	15
White Hills	49	From Hackberry to—	
Gold Basin	66	Music Mountain	25
Cedar via Yucca	51	Gold Basin	40
Eldorado Canyon, Nev.	74	Lost Basin	50
Virginia Camp	40	Scanlan Ferry	60
Sheeptrail Mines	28	Signal	85

Stage lines run from Kingman to Gold Road and to Cerbat daily except Sunday. Semiweekly service is maintained from Hackberry, via Big Sandy, to Signal and to Gold Basin; also from Chloride to White Hills and Eldorado Canyon.

PHYSIOGRAPHIC FEATURES.

COLORADO PLATEAU.

As shown by Gilbert, Marvine, and others, northwestern Arizona lies mainly in two well-known provinces, the high Colorado Plateau on the east and the Great Basin on the west. These provinces, which reach their best development and are best known in Nevada and Utah, maintain in their southern extension into Arizona the relation which they have farther north. This relation is well expressed in the northern part of the area delineated on Plate I, where the Grand Wash Cliffs, extending from Music Mountain in a northwesterly direction across Colorado River, form for the most part a sharp boundary line between the Grand Canyon country, or Colorado Plateau province, on the east and the Great Basin on the west. Along this line descent is made from the plateau, at an elevation of 6,500 feet, by steep, rocky cliffs, bluffs, and finally talus slopes, into the basin 3,000 feet below. The dominant features of the plateau in this portion of Arizona are benched mesas or table-lands, composed of generally horizontal stratified rocks. Through this table-land area the deep trench of the Grand Canyon of the Colorado has been cut.

GREAT BASIN PROVINCE.

The chief features of the Great Basin portion of the area—the portion with which this paper is principally concerned—consist of ranges of mountains trending nearly north and south and separated by broad, plain-like, detritus-filled valleys.[a] On the west lies the great trough of Colorado River, which has cut through these desert ranges without greatly modifying the general physiography of the country.

DRAINAGE.

The entire area drains into Colorado River. In most of the northern portion, that which extends westward from the Colorado Plateau, the drainage flows northward, chiefly by way of Hualpai Wash and Detrital Valley, to the Colorado below the mouth of the Grand Canyon, just beyond the northern edge of the area. The drainage of the southern portion of the area finds its way to the Colorado

[a] For a single map showing comprehensively the great number and distribution of these ranges in the adjoining States of Nevada and California, see Bull. U. S. Geol. Survey No. 208, 1903, Pl. I.

chiefly by way of Big Sandy Wash, a tributary of Williams River, on the southeast and Sacramento Wash on the southwest.

RELIEF.

The altitude of the area ranges from 500 feet in the southwestern part to nearly 8,300 feet on Hualpai Peak, the highest mountain, the total vertical range being thus about 7,800 feet. The mountains collectively average somewhat less than 5,000 feet in elevation, the valleys about 2,500 feet, and the land mass of the area as a whole about 4,000 feet. The general slope of the area is southwestward toward Colorado River.

MOUNTAINS.

The mountain ranges trend north-northwest, nearly parallel with the edge of the plateau. They seem in general to be due to erosion, but some are, in part at least, deformational ranges or fault blocks. They exhibit considerable variation in height, but for the most part rise about 3,000 feet above the neighboring valleys and are generally rugged. Like the valleys, they average 10 or 12 miles in width, and their aggregate area is about equal to that of the valleys. They are composed in the main of pre-Cambrian granitoid and metamorphic rocks, flanked or overlain by younger rocks of volcanic origin. The sedimentary deposits of the Colorado Plateau, which at one time must have covered this entire area and which, according to Spurr,[a] as folded strata compose the mountains in the Nevada and Utah portion of the Great Basin, have here been completely removed by erosion.

The ranges west of the Grand Wash Cliffs, as represented on the map, are three in number—the Cerbat Range, the Black Mountains, and, west of Colorado River, the Eldorado Range. This paper deals chiefly with the Cerbat Range and the Black Mountains.

GRAND WASH CLIFFS.

The Grand Wash Cliffs constitute the great break of the Colorado Plateau into the Great Basin. They undoubtedly represent a fault line, as has been described by previous writers, and are so shown on the accompanying map (Pl. I).[b] Dutton[c] describes the Grand Wash fault as a gigantic displacement in which the whole country to the west has dropped down 6,000 or 7,000 feet. This fault is best developed along the edge of the plateau, extending from the mouth of the Grand Canyon southeastward to Music Mountain, a distance of about 50 miles, with a height of escarpment of about 3,000 feet

[a] Spurr, J. E., Bull. U. S. Geol. Survey No. 208, 1903, p. 133.

[b] The faults here shown are copied from Lee, W. T., Geologic reconnaissance of a part of western Arizona: Bull. U. S. Geol. Survey No. 352, 1908, Pl. I.

[c] Dutton, C. E., Second Ann. Rept. U. S. Geol. Survey, 1882, p. 126.

and an average width of about 3 miles. The regularity of its course is locally interrupted by embayments or short, deep canyons cut back into the plateau, the most marked example being that at Clay Spring, north of Music Mountain camp.

From the edge of the plateau the general trend of the slope is west-southwest into Hualpai Valley. Typically this slope is made up of three topographic elements; these are, in descending order, (1) an upper, more or less precipitous cliff or scarp, about 1,500 feet in height, composed of the nearly horizontal strata of the Grand Canyon section; (2) an intermediate mountainous belt, in many places steep and rugged, composed of pre-Cambrian rocks having a vertical range of 1,000 or more feet and a breadth of about 2 miles; (3) a less steep foothill belt of irregular hills and ridges, consisting of similar granitoid rocks, which, with immense local deposits or fans of steep-lying talus or coarse, mostly granitoid, débris, descend from 600 to 1,000 feet to the edge of the valley.

At Music Mountain the Grand Wash Cliffs divide, the upper or sedimentary portion extending eastward under the name of Yampai Cliffs, and the lower or crystalline portion continuing southward under the names of Cottonwood Cliffs and Aquarius Cliffs, forming the edge of the Truxton Plateau.

CERBAT RANGE.

The Cerbat Range extends nearly north and south through the middle of the area. In the latitude of Music Mountain it lies about 16 miles west of the Grand Wash Cliffs, which it in general parallels and from which it is separated in the northern part of the area by Hualpai Valley, 15 miles wide, and in the southern part by Big Sandy Valley, 10 or 12 miles wide.

The Cerbat is a broken range. As originally used by Lieutenant Whipple the term includes the Cerbat Mountains, the Hualpai Mountains on the south, and the White Hills on the north. Lee includes, in addition, the Aubrey Hills, a small group of low mountains to the south of the Hualpais. The range is the direct southerly extension of the Virgin Mountains, across Colorado River, in Nevada.

Cerbat Mountains.—The most important part of the range, so far as the present discussion is concerned, is the group known as the Cerbat Mountains, which lie in the central part of the area, between the Hualpai Valley on the east and the Detrital-Sacramento Valley on the west. On the north they are separated from the White Hills by a very low, detritus-filled pass, directly connecting the detrital deposits of the Hualpai Valley with those of the Detrital Valley. On the south, however, the Cerbat Mountains are somewhat loosely connected with the Hualpai Mountains by an intervening low, dis-

sected volcanic mesa, whose surface lies but a few hundred feet above Kingman, situated near its center, and which for convenience of reference may be designated the Kingman Mesa. (See Pl. IV, *A*.)

The Cerbat Mountains have a length of about 30 miles and an average width of about 10 miles. They attain their maximum width—about 12 miles—just north of Chloride, which is situated near the middle of their western border. They are high and rugged, and seem to be essentially of erosional origin.

The most important valleys, so far as mining interests are concerned, are those in which lie Cerbat, Todd Basin, Mineral Park, and Tennessee washes on the west and Stockton Hill, I. X. L. Basin, and the C. O. D. washes on the east. These valleys head near the axis of the mountains and debouch on the plains at right angles to its trend. The mountains are composed of pre-Cambrian granitic rocks, with their edges locally flanked on the west and south by Tertiary volcanic rocks and on the east by younger basalts. The crest line lies at about 6,000 feet, or 3,000 feet above the adjacent valleys. The culminating peaks are Cherums Peak, near Chloride, and Mount Tipton, at the north end of the group, both of which reach altitudes of about 7,000 feet.

White Hills.—The White Hills are situated in the north-central part of the area, north of the Cerbat Mountains, between Hualpai Wash on the east and the Detrital Valley on the west. They consist of a belt of low hills about 15 miles in width, extending northward for 25 miles to Colorado River. Here the Virgin Canyon separates them from the Virgin Mountains on the north. They rise from 100 to 2,000 feet above the valleys on either side, but nowhere do they attain an elevation of 5,000 feet, and their topography is in the main of a gentle type. The White Hills are composed of pre-Cambrian granitoid rocks, covered locally with Tertiary volcanic rocks or younger basalt and patches of Quaternary conglomerate and gravels.

Hualpai Mountains.—The Hualpai Mountains lie in the southeastern part of the area, southeast of the Cerbat Mountains, south of Hualpai Wash, and between the Big Sandy Valley on the east and the Sacramento Valley on the west. They extend from the latitude of Kingman southward a few miles beyond the limits of the area shown on the map (Pl. I, in pocket), in which direction they have a length of about 40 miles. On the north they have a width of about 16 miles, which, however, diminishes somewhat within a short distance to the south. Their average height, as given by Lee, is 7,000 feet. Their culminating point is Hualpai Peak, which is situated in the northern part of the group, 11 miles southeast of Kingman, and attains the altitude of 8,266 feet.

These mountains are composed of pre-Cambrian granitic rocks and seem to be a fault block tilted eastward. The precipitous western

slope, according to Lee, meets the detrital plain of the Sacramento Valley at high angles. Its base is flanked on the north by the Kingman Mesa, and similar flat lava-topped buttes and hills, rising a few hundred feet above the surrounding plain, extend southward nearly to the south end of the range.

The eastern slope of the mountains, according to Lee,[a] is not so precipitous as the western. He says:

> At altitudes of nearly 6,000 feet the crystalline rocks begin to disappear beneath a corrugated detrital slope of comparatively low gradient, which extends eastward to Big Sandy Wash, a distance of 10 to 15 miles. In this distance the descent is about the same as that attained in the western slope in a much less distance.
>
> At the southern end of the range the mountains cease rather abruptly, giving place to low isolated hills separated by broad passes occupied by the detrital accumulation of the plains. To the east are several comparatively small spurs and detached mountain groups.

Peacock Mountains.—Northeast of the Hualpai Mountains, lying between them and the Cottonwood Cliffs and interrupting the continuity between the Hualpai and Big Sandy valleys, are the Peacock Mountains, an outlying group having a length of 20 miles and a width of 6 or 7 miles. Like the Hualpai Mountains, they are composed of pre-Cambrian granitic rocks and have their steeper slope on the west. They culminate in Peacock Peak, a few miles southeast of Hackberry, near the middle of the group, at an altitude of 6,268 feet.

BLACK MOUNTAINS, OR COLORADO RANGE.

In the western part of the area and the extreme western part of Arizona, lying between the Detrital-Sacramento Valley on the east and the great trough of Colorado River on the west, are the Black Mountains, known by the early writers as the Blue Range and on the Wheeler maps and in a still later report by Spurr as the Colorado Range. At present this range is often called the River Range, but it is more generally known as the Black Mountains, and this name has been adopted for it by the United States Geographic Board.

This range is the southern extension of the Muddy Range in southeastern Nevada, from which it is separated on the north by Boulder Canyon, situated east of the Great Bend of the Colorado. It extends from Boulder Canyon for 100 miles southward, to the valley of Sacramento Wash, or nearly to the southern edge of the mapped area, east of Needles. Though continuous throughout, it is more or less irregular in height and width. It varies in width locally from 5 or 6 miles in the northern and middle parts to 10 miles or more in the southern part; and the crest line varies in altitude from

[a] Lee, W. T., Geologic reconnaissance of a part of western Arizona: Bull. U. S. Geol. Survey No. 352, 1908, p. 24.

5,500 feet in Mount Perkins and Mount Wilson to about 3,000 feet in Eldorado Pass, west of the White Hills.

The topography is, in the main, that typical of a mass of volcanic flows eroded into rugged peaks, ridges, cliffs, canyons, and gorges. In some regions, however, where erosion has been less intense, the original type of table-land and mesas is still preserved. As shown in figure 2, the usually short eastern slope meets the plain of the Detrital-Sacramento Valley at an average elevation of about 2,000 feet; the long western slope descends to Colorado River, which here flows at an average elevation of about 540 feet.

Much of the northern portion of the range, however, lies close to the river, where its rocks form the walls of the Black Canyon of the Colorado. According to Newberry,[a] a magnificent exposure of volcanic rocks is displayed at this locality. Toward the south, however, broad, gravel-covered, inclined, graded planes or mesas, 2 to 5 miles in width, intervene between the mountains and the river or the alluvial flats which locally border it.

The range is essentially composed of the pre-Cambrian granitoid complex, flanked or overlain, and in the southern part deeply buried, by extensive areas of Tertiary volcanics. A few smaller batholiths of granite porphyry or quartz monzonite of intermediate age are intruded into the pre-Cambrian rocks.

Topographically the range consists of five groups of mountains—the Mount Wilson, Perkins, Detrital-Sacramento, Mount Nutt, and Black Mesa groups, named in order from north to south.

The Mount Wilson group, named from its highest peak, which is situated toward its northern part and has an altitude of 5,500 feet, extends from Boulder Canyon southward to Eldorado Pass, a distance of about 25 miles. From Mount Wilson the altitude diminishes to about 3,000 feet at Boulder Canyon on the north and at Eldorado Pass on the south. The rugged western slope presents a view which for "wild, savage grandeur" Newberry describes as scarcely equaled by anything he had seen elsewhere.

The Mount Perkins group, an elongated ridge, extends from Eldorado Pass southward to Union Pass, a distance of 40 miles. It culminates in Mount Perkins, 5,500 feet high, situated near the center of the group. From this peak southward the altitude diminishes to 3,500 feet at Union Pass. The southern lava-covered portion of this group is, in part, of a mesa type.

The Detrital-Sacramento group occupies an area about 8 miles in diameter and extends eastward from the southern part of the Mount Perkins group nearly across the Detrital-Sacramento Valley southeast of Chloride, forming for the most part the divide between

[a] Newberry, J. S., Geological report (Ives, J. C., Report upon the Colorado River of the West, pt. 3), 1861, p. 40.

the Detrital Valley on the north and the Sacramento Valley on the south. It is composed of many small, irregular hills of basaltic rock.

The Mount Nutt group, of which Mount Nutt, 5,000 feet high, situated south of the center, is the culminating peak, extends from Union Pass southward to Gold Road (formerly Sitgreaves) Pass. It is a rugged group, composed of volcanic rocks with precipitous fault scarps along most of its southern and western portions. At Gold Road Pass the altitude of the crest line diminishes to 3,550 feet. In the latitude of Secret Pass (elevation 3,400 feet) the range is tripartite, being composed of three well-defined, north-south ridges, situated 2 or 3 miles apart.

The Black Mesa group extends from Gold Road Pass southward to the end of the range at Sacramento Wash, which is traversed by the Atchison, Topeka and Santa Fe Railway. It has a length of 20 miles, a width of about 10 miles, and an average elevation of about 4,000 feet. It diminishes in altitude toward the south. Its topographic form is the result of deep dissection of a huge volcanic plateau known as Black Mesa, whose rocks are about 3,000 feet in thickness and which formerly had a much wider extent. At the eastern portion the mountains form a relatively regular escarpment, rising about 1,000 feet above the Sacramento Valley; the western border is more deeply eroded and irregular, with projecting ridges and peaks, of which Boundary Cone and Leland and Hardy mountains are examples.

The mountains shown at the lower edge of the map, extending south of the railway along Colorado River, are a part of the Mohave Mountains on the east and of the group known as the Needles on the west. They are composed essentially of Tertiary volcanic rocks, and 8 or 10 miles southeast of Mellen connect with the Chemehuevis Mountains, which are made up of the pre-Cambrian complex.

ELDORADO RANGE.

Rising from the great trough of the Colorado on the west is the Eldorado Range, whose eastern slope only is represented on the accompanying map. This range is topographically and geologically similar to the Black Mountains, from which Colorado River separates it on the east, being composed of the same classes of rocks, with a somewhat greater proportion of monzonite and syenite. The Tertiary volcanic rocks predominate in the northern part and the pre-Cambrian crystalline complex in the southern part. The highest point is Dead Mountain, which has an altitude of nearly 6,000 feet and is situated near the middle of the range. Although the range does not properly form a part of the area here described, this brief sketch of it is given because it has close geographic, geologic, and

economic relations with this area. It contains the Searchlight, Eldorado Canyon, and other producing mining camps.

VALLEYS.

DETRITAL-SACRAMENTO VALLEY.

The principal valleys of the area, apart from the great trough of the Colorado, are the Detrital-Sacramento and the Hualpai. The former lies between the Cerbat Range on the east and the Black Mountains on the west. As defined by Lee,[a] it extends from Colorado River on the north to Williams River, 30 miles beyond the area mapped in Plate I, on the south, and between these points has a length of 130 miles and a width of 5 to 15 miles.

In the region of Chloride the valley is traversed by a low divide separating the drainage of the northern part from that of the southern part. The portion north of this divide, known as the Detrital Valley, drains northward by way of Detrital Wash, which empties into the Colorado between Virgin and Boulder canyons. The central portion, known as the Sacramento Valley, drains southward via Sacramento Wash, which joins the Colorado at Mellen. The portion south of Sacramento Wash has no distinctive name.

As noted by Newberry, Lee, and others, the Detrital-Sacramento Valley seems to be due mainly to erosion and must have been at one time occupied by a large river. The depth to which it was eroded is estimated by Lee, who has examined it on the north and on the south, as probably more than 2,500 feet; the amount of filling it contains, consisting of detrital deposits of conglomerate, sand, gravel, wash, clay, and intercalated sheets of basalt, is not known. Since the infilling, however, considerable erosion has taken place.

HUALPAI VALLEY.

The Hualpai Valley is situated northeast of the central part of the area, between the Grand Wash Cliffs on the east and northeast, the Cerbat Mountains and White Hills on the west, and the Peacock and Hualpai mountains on the south. It is about 75 miles long and 25 miles wide. It is for the most part an undrained basin; the lower portion, which has an elevation of about 3,000 feet and is about 16 miles in length by 10 miles in width, is known as Red Lake. This "lake," however, is a playa, or dry, barren, mud flat most of the time, owing to the evaporation of the flood waters or their absorption by the underlying filling of the valley. The principal drainage entering the basin comes through Truxton Creek, the bed of which is usually dry.

[a] Bull. U. S. Geol. Survey No. 352, 1908, p. 52.

The Hualpai Valley is a structural trough situated in direct alignment with the Grand Wash fault extending southward from the mouth of the Grand Canyon, where, according to Dutton, the throw is from 6,000 to 7,000 feet. According to Gilbert [a] it occupies a pseudomonocline formed by the fault. As suggested by Lee, this fault probably extends through the valley and is continuous with that west of the Hualpai Mountains.

Other evidences of deformation are tilted basalt sheets exposed in buttes and ridges dipping eastward beneath the floor of the valley along its western edge, and according to Lee the sedimentary rocks at the north end of the valley are also tilted to the east.

The thickness of the filling contained in the valley is unknown. A well 700 feet deep near the head of Hualpai Wash does not go through it.

The northern part of the valley, known as Hualpai Wash, is very much narrower than the main valley and has a length of 25 miles; it drains northward into the Colorado at Scanlon Ferry. It is a structural depression, and in its lower part contracts almost to a canyon. The divide at its head, which separates it from the undrained portion of the valley, rises but 300 feet above Red Lake and in time will probably be lowered by back cutting so that the lake will be drained by the wash.

BIG SANDY VALLEY.

The Big Sandy Valley is situated in the southeastern part of the area, between the Cottonwood and Aquarius cliffs on the east and the Hualpai Mountains and Aubrey Hills on the west. It extends from Hackberry southward to Bill Williams River, a distance of 75 miles, and has a width of 10 or 12 miles. The lowest portion of the valley occurring within the area here described is Big Sandy Wash, whose principal tributaries from the plateau region on the east are White Cliff, Trout, and Sycamore creeks. According to Lee, these streams enter the Big Sandy through deep, narrow canyons. He continues: [b]

> That portion of the valley between the Hualpai Mountains and Big Sandy Wash consists of a long, graded detrital slope, more or less deeply cut by parallel washes, such as Deluge Wash. This highly inclined detrital slope, the western fault scarp of the Hualpai Mountains, and the fault scarp to the east (Aquarius Cliffs) all terminate at the south in practically the same latitude.

Big Sandy Valley, as defined by Lee,[c] is a fault trough formed by the downthrow of the Hualpai Mountain block on the east, as marked by the fault extending southward along the Cottonwood and Aquarius cliffs. The overlying Tertiary volcanic rocks, having been

[a] Gilbert, G. K., U. S. Geog. and Geol. Surveys W. 100th Mer., vol. 3, 1875, p. 60.
[b] Lee, W. T., Bull. U. S. Geol. Survey No. 352, 1908, p. 50.
[c] Idem, pp. 50–51.

dropped from the level of the plateau on the east, now floor the valley and abut against the underlying granite along the fault plane at the base of the cliffs. The detrital filling of the valley, according to Lee, consists of several formations of sand, gravel, clay, tufa, etc., that are unconformable with one another. They represent different periods of deposition and aggregate 1,000 feet or more in thickness.

GREAT TROUGH OF THE COLORADO.

Location and character.—A most striking feature of the area is the great trough of Colorado River, extending north and south along its western border between the Black Mountains on the east and the Eldorado Range on the west. Its great sides, sloping from the crests of the ranges, 5,000 to 6,000 feet in altitude, meet in the bed of the river, which here flows at an altitude of about 540 feet. The floor of the stream is in some places bed rock; in others it consists of deposits of infilled débris of unknown thickness. The bottom of the trough consists mainly of stretches of open valley alternating with usually shorter canyons, whose steep walls rise precipitously above the river, locally to heights of more than 1,000 feet. Of these the most important are Black and Pyramid canyons.

The principal features of the trough were early described by Newberry, who, in association with the Ives expedition in 1857–58, ascended the river to Fortification Rock, situated above Black Canyon in the big bend of the river.

Black Canyon.—Black Canyon is situated in the northwest corner of the area, between the Detrital basin on the north and the basin of Cottonwood Valley, heading a few miles above Eldorado Ferry on the south. It has a length of about 18 miles and consists of a deep, narrow rock gorge, with few interruptions and no open valleys or alluvial deposits. The nearly perpendicular walls on either side of the water's edge rise to heights of 1,000 feet or more. According to Lee and Newberry, they are composed mainly of massive rhyolite, with pre-Cambrian granite in places outcropping at the base.

Cottonwood Valley.—Between Black Canyon on the north and Pyramid Canyon on the south the Colorado flows through an open basin-like area 30 miles long. It is the northernmost of a series of similar areas which extend southward to the Gulf of California. Its central part is known as Cottonwood Valley. Its flood plain bordering the river is in turn bordered by gravel bluffs between which and the foot of the mountains, 4 or 5 miles distant on either side, " are long corrugated slopes covered with angular rock débris or wash from the mountains " and local areas of basalt sheets.

Pyramid Canyon.—Pyramid Canyon lies about west of Union Pass, between the basin of Cottonwood Valley on the north and Mohave Valley on the south, Pyramid being located at its head. It

has a length of about 8 miles. Its depth is only 300 feet, but it is steep walled and is cut in the pre-Cambrian granitoid rocks, which here form a low neck extending from Dead Mountain eastward across the bottom of the trough to the base of the Black Mountains. Surmounting the granite cliffs on either side at 250 to 300 feet above the river are deposits of stratified gravel, similar to and continuous with those occurring above and below the canyon.

Mohave Valley.—Mohave Valley is the largest of the basin-like areas along the lower Colorado. It is elliptical in outline, being about 35 miles long and 15 miles broad. It extends from the foot of Pyramid Canyon southward to the Needles and Mohave mountains and is practically surrounded by ranges of rugged and picturesque desert mountains.

From the bases of the mountains long débris-covered slopes extend toward the river, giving way to gravel-covered mesas that descend in a succession of half a dozen terraces to the alluvial flood plain, about 80 square miles in area, bordering the river in the center of the valley.

GEOLOGY.

PRINCIPAL ROCK GROUPS.

The principal rocks of the region, beginning with the oldest, are the pre-Cambrian crystalline complex, the Paleozoic sediments, the post-Paleozoic intrusive rocks, the Tertiary lavas, and the Quaternary and recent sediments. They are approximately outlined on Plate I (in pocket). As detailed descriptions of them will be given under the heads of the camps in which they occur, only a general sketch is here attempted. With reference to the mineral deposits the first and third of the divisions mentioned are the most important.

PRE-CAMBRIAN ROCKS.

CHARACTER AND DISTRIBUTION.

The fundamental and oldest rocks of the area are those of the pre-Cambrian crystalline complex, which consists essentially of coarse, more or less porphyritic and roughly gneissoid granitic rocks, with gneiss and schist of various kinds. Altered sedimentary rocks may possibly be present in the complex, but of this there is little evidence. It contains numerous quartz veins or lodes in which occur the mineral deposits mined in the Cerbat Range and Grand Wash Cliffs and in part in the Black Mountains.

Though locally concealed, the pre-Cambrian complex underlies the area as a whole and constitutes the uneven floor upon which all the other rocks rest. It forms the larger part of the Grand Wash Cliffs, and extends eastward beneath the Paleozoic rocks of the Grand Canyon district. As shown by its outcrop area on the accompanying

map (Pl. I), it composes the greater portion of the White Hills and practically the whole of the Cerbat, Hualpai, and Peacock mountains. It is also the principal rock mass in the northern part of the Black Mountains. On the west side of the region it outcrops along the Colorado near Black and Pyramid canyons and beyond the river in the vicinity of Eldorado Canyon, Dead Mountain, and at other points in the Eldorado Range.

Outlying knobs and isolated outcrops, together with borings and exposures in washes and canyons, show that the pre-Cambrian complex extends from range to range beneath the detrital deposits of Hualpai and Detrital-Sacramento valleys, and thus continuously underlies the entire area.

PETROGRAPHY.

As a whole, the pre-Cambrian rocks consist of gneissoid granites, which are of varying degrees of schistosity, but which always preserve indications of their igneous origin. They are coarse grained and usually gray or reddish in color and consist of quartz, microcline, orthoclase, microperthite, oligoclase, and small amounts of biotite. The original structure is eugranitic. With increasing schistosity the crushing of the constituents becomes more apparent and muscovite develops from feldspar and biotite, while chlorite forms from the biotite. Garnet of pale reddish color is present in some of the rocks. Pegmatites and aplites are noted from many places and are evidently merely facies or products of differentiation of the prevailing rock.

At Stockton Hill, in the Cerbat Range, the gneisses are in places more schistose with accompanying development of chlorite. There also occurs an amphibolite, containing brown hornblende, labradorite, and magnetite; this rock is a pressed diorite. Other similar rocks contain hornblende, orthoclase, andesine (?), titanite, and magnetite. Entirely similar rocks were observed in the Chloride and Cerbat districts. In the White Hills, at the north end of the Cerbat Range, the gneisses are decidedly schistose with strong development of sillimanite and sericite. There are also amphibolites composed of light-green hornblende, brown mica, and sericitized feldspar.

In the Gold Basin district a quartz-sericite schist was found in addition to the usual gneisses, but it probably represents only an extreme schistose development of the granite. Coarse microcline granite showing some evidence of pressure appears at the base of the Grand Wash Cliffs, but along with it are found massive quartz monzonites which are probably post-Cambrian in age. The normal coarse gneissoid microcline granites prevail in the Union Pass district of the Black Mountains, toward the Colorado River side. Some of these are unusually schistose with remaining "augen" of microcline.

Of the specimens of gneisses and schists examined none indicated a sedimentary origin, except possibly a graphite schist from the Cerbat Range between Mineral Park and Stockton Hill.

STRUCTURE.

A schistose structure is characteristic of the pre-Cambrian granitic rocks in this region. The trend of the schistosity is, in general, about N. 30° E., with the dip vertical or eastward at usually steep angles; the dominant jointing strikes north-northwest, with the dip vertical or steeply to the east-northeast. This latter direction is also approximately the trend of most of the fissures containing the quartz lodes above referred to.

Besides the general structure above stated, the rocks have suffered material alteration in regions of intensity of movement, such as fault planes or shear zones, the otherwise massive granites being locally converted almost beyond recognition into fissile mica schist, hornblende schist, and other schists.

PALEOZOIC SEDIMENTS.

About the only Paleozoic sediments of the area are those of the Grand Canyon section, forming the upper part or cliff-making portion of the Grand Wash Cliffs and the adjacent portion of the Colorado Plateau. As they have no material bearing on the subject of this paper they may be dismissed with the following brief notice:

The series, taken in ascending order, consists apparently of a basal quartzite and greenish shale, the two constituting what in the Grand Canyon district is called the Tonto group, of Middle Cambrian age, about 1,000 feet in thickness, and resting, as seen at Music Mountain camp, almost horizontally upon the base-leveled surface of the pre-Cambrian crystalline complex above described.

Above the Tonto is 1,000 feet or more of Carboniferous limestone, the Red Wall (lower Pennsylvanian and upper Mississippian), which rises to the adjacent summit of the plateau. It is mostly heavy bedded, is the principal cliff maker of the Grand Wash Cliffs, and seems to be the northwest extension of the great belt of Carboniferous limestone which, extending northwest and southeast across Arizona, has in association with it many of the Territory's mineral deposits.

Above the Red Wall limestone lies an undetermined thickness of the Aubrey group, of Carboniferous (upper Pennsylvanian) age.

These Paleozoic rocks must have formerly extended entirely across the area here described and covered it much the same as they now cover the Grand Canyon district to the northeast, but they have since been largely removed by erosion. The only other localities at which traces of sediments probably belonging to this series were encountered are Silver Creek and Kingman.

Along the road which leads from Silver Creek to the Moss mine, at a point about three-fourths of a mile south of the mine, where the covering of Tertiary volcanic rocks has been more or less removed by erosion, occur a few inconspicuous outcrops of purplish, dark iron-gray, and blackish metamorphosed shale, which seems to rest upon the pre-Cambrian granite exposed near by and probably represents unremoved remnants of the basal portion of the Paleozoic series of the Grand Canyon.

At Kingman material excavated from a well on the ground of Judge Metcalf, in the northwestern part of the town, contains limestone bearing organic remains, and may be related to the Paleozoic rocks above described.

INTRUSIVE ROCKS.

The pre-Cambrian gneisses and schists are in places intruded by igneous masses and dikes which are considerably older than the Tertiary volcanic rocks, next to be described, but whose exact age is unknown. Very likely they are of late Jurassic or early Cretaceous age and of the same period of intrusion as the batholiths of California and western Nevada. The most important of these intrusives are granite porphyries of varying types and dark lamprophyric dike rocks such as minettes and vogesites. Being similar in composition to the pre-Cambrian granites, the younger granites and porphyries are in places difficult to distinguish and separate, especially as they show here and there a certain close jointing or schistosity and are nearly everywhere strongly sheeted. The larger stocks of granite porphyry are accompanied by dikes of the same material and by characteristic complementary dikes of minette or vogesite. These intrusives are found in the more important mining districts and are probably connected with the genesis of the ore deposits. Many of the lamprophyric dikes are followed by fissure veins.

GRANITE PORPHYRY AND MICROPEGMATITE.

Granite porphyry occurs mainly in the Cerbat Mountains, where it extends with interruptions from Stockton Hill to Chloride. It is practically coextensive with the mineral belt of the mountains. The principal masses, however, occur in the Mineral Park district, where the granite porphyry forms the upper part of the prominent knob on the northwest known as "Niggerhead." It also constitutes a considerable portion of the mountains on the opposite side of the wash to the south, and extends with interruptions throughout the greater portion of the basin eastward for a distance of 1½ miles into the slope of the range. Its sheeting or jointing, well shown across the northern part of the Mineral Park district, dips westward at angles of about 35°.

In a fresh specimen the rock is light gray to white and of medium to fine grain. Thin sections show it to be a coarse granite porphyry with phenocrysts of quartz and orthoclase in a microcrystalline groundmass. The rock contains some secondary sericite and is greatly crushed. There are many types of this rock in the Music Mountain district, and particularly in the dikes of the Cerbat Range. A specimen from Charcoal Canyon shows large phenocrysts of quartz, oligoclase (?), biotite, and hornblende, the latter two largely converted into chlorite. The groundmass is microgranular and consists of quartz and orthoclase.

A dike from the Lucky Boy mine in the Chloride district approaches a syenite porphyry, but contains no biotite or hornblende. Others look very much like aplites in thin section.

An allied rock occurs in two masses in the Black Mountains. One of these makes up the Hardy Mountains, an outlying group several miles in diameter, about 2½ miles west of Gold Road. The other occupies an area embracing the hills near the Moss mine, 4 miles northwest of Gold Road. The rock is pinkish, is of medium to coarse grain, and is composed of quartz, orthoclase, and microperthite, in micropegmatitic intergrowth. The accessory minerals consist of a few crystals of iron ore, biotite, sphene, zircon, and apatite. The feldspars are clouded with kaolinite, and a little calcite is also present. The quartz contains numerous fluid inclusions and negative crystals. These usually contain a bubble of gas and some of them a colorless crystal of a double refracting mineral.

A partial analysis, by E. C. Sullivan, of a specimen from the Navy group mine, 4 miles northwest of Gold Road, gave: SiO_2, 73.16; CaO, 1.35; Na_2O, 3.71; K_2O, 5.21. This rock is perhaps best termed a micropegmatite. Some varieties range toward a quartz syenite porphyry.

Quartz monzonites and hornblende granites occur in the Music Mountain district, as later intrusives in the pre-Cambrian gneisses.

LAMPROPHYRIC DIKE ROCKS.

Many acidic intrusive masses are accompanied by narrow dikes of a basic character and peculiar structure. In the Cerbat Mountains a number of these dikes were noted. They are found at the Minnesota-Connor and Towne mines in the Chloride district, at the Champion and Windy Point mines in the Cerbat and Mineral Park districts, and at many other places.

The rock is black when fresh, but in many places appears altered and has a brownish or greenish earthy aspect. It usually contains phenocrysts of brown biotite and, in thin section, shows a panidiomorphic structure.

According to their mineral composition the rocks are termed minette, kersantite, or vogesite. A characteristic specimen from the Champion mine (No. 46) was analyzed. It has porphyritic structure, with abundant phenocrysts of biotite and a few of augite. The panidiomorphic groundmass is composed of andesine, augite, orthoclase, iron ore, and apatite. Named in the order of their relative abundance, the constituent minerals are andesine, biotite, augite, orthoclase, iron ore, and apatite. In general the order of crystallization may be stated as follows: Apatite, iron ore, augite, andesine, biotite, and orthoclase. Exceptions to this order will be noted later. The andesine occurs mainly in fine lath-shaped crystals. It contains inclusions of apatite and iron ore, but rarely biotite, and it is only exceptionally that the plagioclase is included in the latter mineral. The light-brown biotite occurs in foils and well-formed crystals containing abundant inclusions of the earlier minerals as noted. The pale-green augite is usually in granules, though here and there it shows crystal forms. Orthoclase was the latest mineral to crystallize and usually fills the space between the other constituents, though some small crystals appear to have formed earlier. Iron ore forms several per cent of the rock. The analysis indicates a titaniferous magnetite. Apatite, as calculated from the analysis, forms 2.02 per cent. The minerals for the most part show little alteration. Some of the feldspar has been replaced by carbonate. A green fibrous chloritic mineral frequently associated with biotite is plentiful. Needle-like crystals of a highly refracting character are abundant in nearly all the minerals. The rock stands between a minette and a kersantite.

Analyses of minette and vogesite.

[George Steiger, analyst.]

	1.	2.
SiO_2	49.59	48.3
Al_2O_3	15.30	.....
Fe_2O_3	5.01	.....
FeO	4.19	5.3
MgO	4.50	.....
CaO	5.51	7.4
Na_2O	2.24	3.1
K_2O	3.80	2.1
H_2O-	2.98	.....
H_2O+	3.59	.....
TiO_2	1.50	.....
ZrO_2	.05	.....
CO_2	None.	1.1
P_2O_5	.94	.....
S	.09	.....
MnO	.11	.....
BaO	.21	.....
SrO	.12	.....
	99.73	.....

1. Dike rock (No. 46) from Champion mine, Cerbat district.
2. Dike rock (No. 100) from Minnesota-Connor mine, Chloride district.

The calculation of the norm of No. 1 is unsatisfactory on account of the large amount of water, which is not taken into consideration in the quantitative system of rock classification. It leads, however, to the placing of the rock as a shoshonose.[a]

The analysis indicates clearly that the rock is a product of differentiation; the high percentages of phosphorus, titanium, barium, and strontium are noteworthy. Still more peculiar is the high percentage of water driven off above 110°. The rock is fresh, on the whole, and the small amount of chlorite can not account for the water. It is difficult to avoid the belief that the rock contains some analcite that is so hidden as to be scarcely detectable under the microscope.

The dike rock from the Minnesota-Connor mine (No. 2) is a rather fine-grained rock with a few phenocrysts of feldspar. The primary minerals are, in order of abundance, orthoclase, plagioclase, and basaltic hornblende; the accessories, biotite, iron ore, and apatite. The secondary minerals are chlorite, sericite, calcite, epidote, kaolinite, zoisite, green amphibole, and pyrite. A brown hornblende was the earliest of the essential minerals to crystallize, following the apatite and iron ore; orthoclase crystallized last, though this was in part contemporaneous with the plagioclase. The feldspars are highly altered, making accurate determinations uncertain. Orthoclase is probably slightly more abundant than plagioclase. Several crystals of plagioclase were determined as andesine and one as labradorite. Probably most of it is andesine. Sericite, epidote, calcite, chlorite, kaolinite, and zoisite were all recognized as alteration minerals in the feldspar. Many of the hornblende crystals show an alteration around the margins to green amphibole, and some have been replaced by chlorite and epidote. Only a few crystals of biotite were recognized. This rock has the mineral composition of vogesite though it is close to the line between vogesite and camptonite.

DIABASE.

Dikes of normal though locally chloritized diabase were noted at the Ellen Jane mine in the Music Mountain district and at the Champion, Hercules, Treasure Hill, Gem, and Midnight mines in the Cerbat Range. They probably belong to the older (Mesozoic ?) intrusive rocks. Other dikes in the Black Mountains are more likely holocrystalline facies of Tertiary basalts.

[a] Washington, H. S., Chemical analyses of igneous rocks, published from 1884 to 1900, with a critical discussion of the character and use of analyses: Prof. Paper U. S. Geol. Survey No. 14, 1903, p. 266.

TERTIARY VOLCANIC ROCKS.

GENERAL FEATURES.

The great event that took place after the erosion of the Paleozoic sediments from the Great Basin portion of the area was the eruption and effusion of a mass of Tertiary volcanic lavas which more or less completely flooded the region. As shown on the map, the present areas of these rocks, which vary from local outcrops to mountain masses several hundred square miles in extent and several thousand feet in thickness, are mere remnants of the former vast lava field which extended over the entire region.

The rocks consist of andesites, trachytes, rhyolites, latites, and basalts, lying in broad superimposed sheets or flows with intercalated beds of ash, tuff, and breccia. They are best developed in the Black Mountains, particularly in the southern part, contain most of the mineral deposits of the range, and probably played an important part in the genesis of these deposits.

Similar effusive rocks are shown by the Wheeler Survey and by Spurr, Ransome, and Ball to continue interruptedly far northward into Nevada and California.

These volcanic rocks have not been differentiated on the accompanying map (Pl. I), but their order of succession is shown in the generalized section (fig. 2) extending across the southern part of the Black Mountains in the vicinity of Gold Road. They rest upon the eroded surface of the pre-Cambrian complex.

BASAL ANDESITE.

The oldest or basal formation of the Tertiary volcanics, as well exposed in the Vivian region, is a light-gray, purple, or pale-green andesite. It has a thickness of at least several hundred feet and occupies the border of the foothills from the vicinity of the Vivian and Leland mines southwestward to the gravel mesas of Colorado River. It is designated No. 9 in figure 2. It consists of flows, tuffs, and breccias. It is more or less chloritic, calcitic, and locally silicified, and is not known to contain mineral deposits of commercial value. It shows a northeasterly sheeting not observed in the overlying rocks and is intruded by the green chloritic andesite to be next described and by rhyolite dikes. Thin sections of specimens obtained near Vivian indicate that this rock is an andesite, though its alteration hardly permits exact determinations.

GREEN CHLORITIC ANDESITE.

Overlying the above-described andesite, and roughly differentiated on the map as green chloritic andesite, is another series of flows of andesite which contains an important part of the mineral-bearing

lodes in the Gold Road region. It is known locally as "antique porphyry." At Secret Pass it rests directly on the pre-Cambrian granite, and in the Hardy Mountains on the granite porphyry or micropegmatite. It occupies an area of 35 or 40 square miles and has a maximum thickness of about 800 feet. It is disposed in heavy beds or flows inclining gently eastward into the range. (See fig. 2.) In places it is associated with or grades into black latite, which could not be differentiated in the field; hence the general use of the term "green chloritic andesite" in this report does not imply that latite may not also be present.

The rock consists mainly of a dark greenish to olive or light-green fine-grained groundmass containing numerous whitish feldspar phenocrysts, which in certain localities constitute about 40 per cent of the volume of the rock and show some degree of parallel disposition due to flow. The phenocrysts vary in appearance from fresh and glassy to dull and are of all shapes and sizes, ranging from minute slender laths to stout, approximately equidimensional prisms having a maximum length of about one-half inch. In the fresh, unaltered rock, irregular black bodies of which occur inclosed in the greenish portion above described, well exposed at the Pasadena mine, the groundmass is black and the phenocrysts are fresh and glassy.

Under the microscope the rock is generally found to be decidedly chloritic and calcitic and in some sections pyritic; in others it con-

FIGURE 2.—Generalized section across Black Mountains. 1, Sands and gravels; 2, undifferentiated volcanic rocks; 3, green chloritic andesite; 4, gneissoid granite; 5, basalt; 6, rhyolite; 7, young andesite; 8, rhyolite tuffs; 9, andesite and andesite tuffs; 10, granite porphyry and micropegmatite; 11, conglomerate.

tains magnetite, but no pyrite, and in others it is silicified. In some localities it is so decomposed that no bisilicates remain. Some slides show characteristic propylitic alteration zones, particularly along veins. The rock is traversed by numerous mineral-bearing veins or lodes, particularly in the Vivian region.

The most important intrusive into this rock is rhyolite in the form of large dikes and rounded pluglike or stocklike masses. The following partial analyses have been made:

Partial analyses of green chloritic andesite.

[Analyst, E. C. Sullivan.]

	1.	2.
SiO_2	53.55	53.13
CaO	5.60	7.9
Na_2O	2.62	2.46
K_2O	3.14	3.13

1. West Gold Road mine, Black Mountains (No. 369).
2. Pasadena mine, Black Mountains (No. 437).

No. 1 is a highly altered greenish porphyritic rock, with abundant phenocrysts of orthoclase and acidic plagioclase, in a groundmass of fine laths of andesine and oligoclase with abundant orthoclase. The accessory minerals are iron ore and apatite, neither being plentiful. The secondary minerals, which form a high percentage of the rock, are, in the order of abundance, chlorite, calcite, epidote, and pyrite. Quartz also occurs, with chlorite and calcite, as filling of small cavities. Though the rock is andesite in character, the mineral composition shows it to be an intermediate rock, and it may be classed as trachytic andesite.

The dark-green andesitic rock (No. 2) contains phenocrysts up to 7 or 8 millimeters in length, of labradorite with a few of orthoclase and an unstriated feldspar with index above Canada balsam. The fine trachytic groundmass is composed of andesine and orthoclase, the latter being but slightly less abundant than the plagioclase feldspar; small crystals of magnetite are abundant. Secondary minerals are chlorite and carbonate, with a little epidote, and form a large percentage of the groundmass. The phenocrysts show less alteration, though all are partly and some entirely replaced by chlorite and carbonate, with sericite in some places. A small vein crossing the slide is filled with quartz, calcite, and adularia.

Like No. 1, this type of the green chloritic andesite is really an intermediate rock standing between the andesites and the trachytes.

At Vivian the rock cuts the earlier andesite as dikes. A specimen of it collected from the Leland mine proved to be latite, as follows:

Partial analysis of latite from lower east tunnel of Leland mine, at Virian, Black Mountains.

[Analyst, E. C. Sullivan.]

SiO_2	56.33
CaO	4
Na_2O	2.60
K_2O	5.19

This is a black, fresh-looking rock with phenocrysts of orthoclase and acidic plagioclase, albite, and oligoclase. The groundmass is composed of the same feldspars, orthoclase being more abundant than plagioclase. Some quartz is present, but very little if any is primary. The accessory minerals are iron ore and apatite, the latter being rather abundant. The secondary minerals are chlorite, calcite, quartz, sericite, and pyrite. Chlorite is abundant throughout the rock. Calcite and quartz occur principally as filling of cavities, though the altered feldspars contain considerable carbonate.

UNDIFFERENTIATED VOLCANIC ROCKS.

Overlying the above-described green chloritic andesite in the Gold Road region are about 2,000 feet of undifferentiated volcanic rocks, consisting of andesites, trachytes, rhyolites, and latites. They compose the bulk of the range in this locality and are important economically, as they contain the Gold Road vein now worked and neighboring prospects. They extend from the region of the Gold Road mine nearly to the summit of the range, and present the rugged cliff, steep slope, and deep gulch topography shown in Plate XI.

Like the andesite just described, these rocks lie in heavy beds slightly tilted and dipping gently eastward into the range, and are cut by several systems of sheeting, the most important of which trends in a northwesterly direction, and has an approximately vertical dip. Like the basal andesite, they consist of flows, tuffs, and breccias. The upper part of the section is essentially rhyolitic.

These rocks are all represented in the Gold Road mine. The andesites are usually green or dark greenish-gray, generally porphyritic, and in some places much resemble the green chloritic andesite. They are locally pyritic. The trachytes are light greenish gray, purple, or red, very porphyritic, and differ markedly from the andesites microscopically and chemically, as may be seen by comparison of the analyses on page 39. The rhyolites range from dense reddish, iron-stained silicified rocks, with banded or platy structure due to flow, to pale greenish, yellowish, pinkish, and whitish porous or massive tuffs.

Microscropic and chemical analyses of the more important of these rocks show that what were called andesites in the field are

really intermediate rocks approaching latite. Some of the members of the series are true trachytes. So far as shown by the analyses even the rocks which would be called andesite from a study of thin sections would show on analysis a high percentage of potassium.

Partial analysis of latite near Mocking Bird mine, Black Mountains.

[Analyst, E. C. Sullivan.]

SiO_2	59.50
CaO	5.60
Na_2O	3.37
K_2O	4.33

This is a purplish-gray rock containing phenocrysts of labradorite and bytownite, as well as foils of biotite, in a fine groundmass composed largely of orthoclase with abundant iron ore. Apatite is plentiful. All the biotite crystals show strong resorption bands of iron ore and the smaller crystals have been entirely resolved. Probably much of the iron ore of the groundmass has resulted from the magmatic alteration of biotite. A number of crystals entirely replaced by carbonate, or carbonate and quartz, appear to be pseudomorphs after pyroxene. Calcite is the most important secondary mineral.

Among the undifferentiated volcanic flows later examinations disclosed some normal trachytes, rocks which are rather uncommon among the Tertiary effusives of the West. These rocks were principally identified from the vicinity of the Gold Road mine. In the field they are not easily distinguished from the andesites and latites, especially as all the rocks are in an altered condition. Their extent is probably great, but can be ascertained only by detailed petrographic field work. The rocks are greenish, partly altered, and locally pyritic, and contain abundant white phenocrysts of sanidine.

The following analyses have been made:

Analyses of trachytes from Black Mountains.

[Analyst, George Steiger.]

	1.	2.	3.
SiO_2	58.74	66.46	65.12
Al_2O_3	15.09	14.14	.....
Fe_2O_3	4.66	4.07	.....
FeO	.84	.40	.....
MgO	2.75	.67	.....
CaO	2.68	.78	.....
Na_2O	.25	1.26	.....
K_2O	8.05	9.26	.....
H_2O-	2.08	.78	.....
H_2O+	3.09	1.28	.....
TiO_2	.98	.83	.....
ZrO_2	.02	.05	.....
CO_2	.61	None.	.....
P_2O_5	.40	.25	.....
S	None.	None.	.....
MnO	.09	.03	.....
BaO	.07	.06	.....
SrO	.04	.03	.....
	100.44	100.35	.....

1. Gold Road mine, face of 80-foot crosscut on 700-foot level (No. 483).
2. Gold Road mine, Billy Bryan drift (No. 414).
3. Line Road tunnel, Gold Road mine (No. 420).

No. 1 is of light greenish-gray color with abundant phenocrysts of tabular sanidine. There are also biotite foils and possibly also prisms of hornblende, but both are altered to chlorite, epidote, serpentine, and very fine grained quartz. The groundmass is of very fine grain, in part probably devitrified glass. The rock has been subjected to propylitic alteration, but this has probably not greatly changed its composition, except that some of the soda is likely to have been leached and that some secondary adularia has formed, with consequent enrichment of potassium. The rock appears to be a normal trachyte.

No. 2 is a brecciated dark purplish-gray rock containing small phenocrysts of orthoclase, albite, also some of biotite, in a fine groundmass composed largely of orthoclase with a little quartz, though this mineral does not appear nearly as abundantly in the section as the chemical analyses would indicate.

The accessory minerals are iron ore, apatite, and a few zircon crystals. The secondary minerals include quartz, iron ore, serpentine, epidote, and sericite. The dark-brown biotite is largely altered. Some crystals are filled with iron ore and have a rim of the same mineral; other crystals have the rim of iron ore, while the center is largely serpentine; and still others have a center of secondary quartz usually accompanied by some serpentine. Quartz occurs in veinlets as well as replacing the mica, and it is probable that most of the free silica shown by the analysis is from these sources. Most of the iron ore appears in the zones of crushing between the breccia fragments and

is probably introduced during the alteration of the rock. Sericite and epidote are present in the feldspar crystals, but neither is abundant. Much of the quartz is secondary, and the rock is without much doubt a trachyte, somewhat affected by propylitic alteration.

Norm of trachyte from Billy Bryan drift, Gold Road mine.

Quartz	22.14
Orthoclase	55.04
Albite	9.96
Anorthite	1.39
Corundum	1.53
Hematite	4.16
Ilmenite	.91
Titanite	.78
Apatite	.50
Enstatite	1.60
	98.01

In the quantitative system this rock is designated as omeose.[a]

No. 3 is a porphyritic rock with phenocrysts of orthoclase and a few of biotite in a cryptocrystalline groundmass composed largely of orthoclase filled with minute specks of a mineral which shows rather strong double refraction and which is probably leucoxene.

The accessory minerals are iron ore, apatite, and a few crystals of zircon and sphene. The secondary minerals are quartz, leucoxene (?), limonite, and serpentine. The mica is a reddish-brown, highly pleochroic variety. Many of the crystals show a rim of iron ore, and some are entirely replaced by iron ore, serpentine, and quartz. The rock is filled with minute veinlets of quartz, and this mineral has partly replaced some of the feldspar crystals. The rock has the mineral composition of trachyte, though the secondary quartz makes it appear high in silica (65.12 per cent).

RHYOLITE SERIES.

The above-described undifferentiated rocks are overlain by a series of rhyolites composed of tuffs, flows, and breccias. In some localities this series attains a thickness of 1,000 feet or more. It extends interruptedly throughout the length of the Black Mountains, and is known as the "water rock," from springs that occur in it. In the Cerbat Range it essentially composes the Kingman Mesa, situated between the Cerbat and Hualpai mountains, where the tuffs seem, in part at least, to be water-laid, and it borders a considerable portion of the Cerbat Mountains on the west. Rhyolite dikes cut nearly all the underlying volcanic rocks as well as the pre-Cambrian complex, and the rhyolite in turn is cut by the younger andesite and basalt.

[a] Washington, H. S., Chemical analyses of igneous rocks, 1884–1900: Prof. Paper U. S. Geol. Survey No. 14, 1903, p. 145.

The rhyolites are as a rule light-colored reddish or pink rocks, with small phenocrysts of biotite, feldspar, and quartz; but they also assume many other aspects and colors, such as dark brown and black. They are normal rocks of their type, as shown by the following analyses and description. The groundmass is felsitic, rarely coarser and microcrystalline.

Analyses of rhyolites from northwestern Arizona.

[Analyst, E. C. Sullivan.]

	1.	2.	3.
SiO_2	72.64	67.03	79.30
CaO	1.42	.66	.16
Na_2O	.46	2.68	1.42
K_2O	9.06	5.36	6.12

1. Mocking Bird mine, Black Mountains (No. 160).
2. Cement rock near Kingman (No. 267).
3. Union Pass, near Hutchinson Camp, Black Mountains (No. 284).

No. 1 is a light-colored rhyolite of tuffaceous aspect. It contains phenocrysts and spherulites of orthoclase, with a few scattering crystals of quartz and biotite in a cryptocrystalline groundmass that is too fine for definite determination of the minerals, but is probably orthoclase and quartz, as indicated by the chemical analyses. The accessory minerals include iron ore, apatite, and zircon. Calcite is rather abundant through the groundmass.

No. 2 is a glassy cellular rock containing scattered crystals of quartz, orthoclase, microperthite, and biotite. There is a little iron ore and a few small highly refracting crystals, probably zircon. Many of the cavities are partly and some entirely filled with amorphous silica. The rock is low in silica and approaches a trachyte.

No. 3 is a pinkish-gray dense rock containing phenocrysts of orthoclase and albite in a microcrystalline groundmass of orthoclase and quartz. It contains a few small apatite crystals. The secondary minerals are confined to small clouded masses, probably carbonate, and altered pyrite crystals.

YOUNGER ANDESITE.

Overlying the rhyolites and locally cutting them as dikes are local flows of dark-reddish andesite which, compared with the andesites already described, has a relatively fresh appearance and is free from the structures that traverse the older rocks. It occurs in the Black Mountains in the Gold Road and Silver Creek regions, and in the Cerbat Mountains north and northwest of Kingman. It is locally amygdaloidal.

OLIVINE BASALT.

The youngest of the effusive rocks is olivine basalt. It occurs in sheets covering the older rocks, including the Quaternary gravels, and cuts them as dikes. It ranges from black to dark iron gray and reddish brown in color, is fine to medium grained, and is locally vesicular or amygdaloidal. At many places its sheets form a series of cliffs or scarps, exhibiting very perfect columnar structure. It originated in two or more periods of eruption separated by intervals of erosion. The thin sections show little that is new or interesting. A basalt from a point 5 miles northwest of Chloride contains some hypersthene, a mineral elsewhere generally absent.

In the Black Mountains both hypocrystalline (glassy) and holocrystalline (diabase) structures occur. The latter development is shown by a basalt from Gold Road Pass.

TERTIARY (?) AND QUATERNARY DETRITAL ROCKS.

Greggs breccia is a name given by Lee[a] to a Tertiary (?) detrital formation filling Grand Wash Trough. Lee describes it as having a thickness of 1,400 feet and being composed of coarse, unassorted, poorly stratified, mostly granitic material, cemented toward the top with lime carbonate, and containing local deposits of travertine.

Temple Bar conglomerate is a name applied by Lee[b] to a Quaternary formation of slightly consolidated sand and gravel which rests unconformably upon the Greggs breccia and older formations and has a wide distribution in southern Arizona. Locally it contains also sheets of basalt, and thus far has yielded no fossils. It occurs in the Colorado and other valleys, filling the low places to elevations of about 3,000 feet. Along the Colorado it is a river deposit, but grades laterally into angular mountain wash. It is regarded as equivalent in age to the detrital accumulations filling the low plains of the Southwest generally and forming the deserts of Arizona and a part of southern California. It is similar to the Gila conglomerate described by Gilbert, Ransome, and Lindgren, and resembles the Lake Bonneville beds described by Gilbert.

The term Chemehuevis gravel is applied by Lee[c] to the series of Quaternary gravels resting unconformably upon the Temple Bar conglomerate and forming terraced bluffs from the mouth of the Grand Canyon to the Gulf. They have a thickness of about 700 feet and are confined to a relatively narrow belt, having been deposited during an aggrading stage of the river.

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[a] Lee, W. T., Bull. U. S. Geol. Survey No. 352, p. 17.
[b] Op. cit., p. 17.
[c] Op. cit., p. 18.

MINERAL DEPOSITS.

DISCOVERY, HISTORY OF MINING DEVELOPMENT, AND PRESENT CONDITIONS.

The discovery of mineral deposits in this area dates from very early in the sixties, when prospectors from the gold mines of California found rich ore on what has since been known as the Moss vein and mine.[a] The Moss mine is situated about 25 miles southwest of Kingman and a few miles north of the old government Camp Mohave trail in the long, sloping belt of country lying between Colorado River on the west and the Black Mountains on the east. It is about 10 miles southeast by east of Hardyville, 12 miles northeast by east of Mohave, 4 miles northwest of Gold Road, and a few miles west of the base of the range, which at that time was known as the Blue Range.

Some of the ore shipped to San Francisco is reported to have been of extremely high value. The report of this rich find brought a rush to the region which, in the years that followed, resulted in extending explorations into the mountains to the east by prospectors from California and Nevada. Owing to the hostility of the Hualpai and Paiute Indians, explorations were for some time confined to the Black Mountains and Cerbat Range, until early in the seventies the inrush from Nevada overawed the savage tribes and made the life of the pioneer less perilous. In 1872 hundreds of men came in from Pioche, Nev., and the gold regions of California, and the rich veins of the Cerbat and Hualpai mountains were discovered. The ores from these veins were so rich that they yielded large profits, although the expense of freight and treatment ran into hundreds of dollars a ton, owing to the fact that the ores had to be packed long distances on burros (there being no roads in the county at the time) to Colorado River, thence by river steamer to Port Isabel, down the gulf to Point Arena, and up the coast to San Francisco, whence they were shipped to England for treatment. Later a small 10-stamp mill was erected at Hardyville to handle the ore from the old Moss mine, but it was not a success, and although one small custom mill was erected at Mineral Park in the later seventies, the above-described method of marketing ores was followed until the advent of the railway in 1882.

[a] At the time of the discovery of the Moss mine this part of Arizona was a part of Dona Ana County, N. Mex. In 1864 Arizona Territory was created, and Mohave County became one of the four political divisions into which the Territory was divided. The county seat was located at Callville, but in 1865, when the State of Nevada was created, that part of Mohave County west of Colorado River, which took in the Vegas and part of the Muddy country, was annexed to the new State, and the county seat was removed to Hardyville. With the influx of people the seat of county government was soon established at Cerbat, where it remained but a few years, being then taken to Mineral Park. In 1887, after the completion of the Santa Fe Railway, the county seat was established at Kingman.

The pioneers suffered untold hardships in the opening of the new country. Supplies had to be brought in by way of the Gulf of California and Colorado River or be freighted over 400 miles of sand and alkali deserts, which made the cost abnormally high. The miners had to pay as high as $2 a pound for black powder. Bacon cost from 35 cents to $1 a pound, sugar 3 pounds for $1, flour 15 to 50 cents a pound, and other things in proportion.

The discovery of silver-gold ores in the mountains of the Cerbat and Hualpai ranges in the early seventies drew the attention of prospectors from the gold mines of the River Range, and for some time the area was classed as a silver-producing region; but a few years ago the low market value of silver stimulated the prospecting for gold. Under the new conditions the first important mine to be opened was the Snowball, near Vivian. This mine showed ore that ran as high as 40 ounces of gold to the ton. It is now embraced in the German-American group of mines. Later the Sheeptrail group, in the upper end of San Francisco district, was opened. One of these mines yielded ore that ran thousands of dollars to the ton. Still later the deposits at the Gold Road mines were found, and it is to these mines that the San Francisco district owes its present prosperity.

For years the country was isolated owing to the lack of railroad connections and was without mining machinery, in consequence of which, up to the eighties, there were very few shafts more than 150 feet deep, although the production of high-grade ores ran well up into the millions, and it was only after the completion of the railroad that the mining era began and practically the first development work below water level was begun. After some years the mining industry drooped again, owing to the further depreciation of silver and to the fact that lower-grade ores were found in depth.

During the last few years, owing to the increase in the price of base metals and the general search for gold deposits, the mining industry has taken on new life, and many properties of well-known merit are being exploited and opened. Abandoned mines are being looked over and their dumps tested and cyanided or milled. The old mines are pumped out and put in shape, and with deeper and more systematic mining new ore shoots are found, and the once so-called "low-grade" bodies of ore are utilized by treatment in the latest milling and value-saving apparatus. In fact, the camps seem to be starting on a new era of prosperity. Naturally, speculators have invaded the area and floated many companies with properties of no or doubtful value; but this seems to be an inevitable accompaniment of any period of intense mining activity.

The establishment of the Arizona-Mexican smelter at Needles, on Colorado River, has provided an outlet for formerly unprofitable ores. The completion of the smelter of the Arizona Smelting Com-

pany, at Humboldt, Yavapai County, near Prescott, added to the facilities for disposing of the ores, but these reduction works were closed during the panic of 1907 and had not been reopened up to the fall of 1908.

The Santa Fe Railway Company has made the following rates on ore shipments from Chloride: Chloride to Needles, from $4.30 a ton for $100 ore to $1.10 a ton for $15 ore; Chloride to Humboldt, from $5.90 a ton for $100 ore to $2 a ton for $15 ore. Rates on shipments of ore or concentrates where the valuation is over $100 and not exceeding $300 are 130 per cent of the $100 rate. These rates are the same as from Kingman, and are the lowest established since the building of the railroad through the county. In general, $20 shipping ore can now be mined at a profit.

MINING DISTRICTS.[a]

The most important legal mining districts in the area here treated are the Wallapai (Hualpai), San Francisco, Weaver, White Hills, Gold Basin, Music Mountain, and Maynard districts. Elsewhere in this report the term "district" will be used in a more general way, without restriction to legal organization at miners' meetings. The term "mining camp" is employed to designate subdivisions of a district. The boundaries of the districts are for the most part uncertain.

The Wallapai district extends from the vicinity of Kingman on the south a little beyond Chloride on the north, a distance of 25 miles. It has a width of 8 or 10 miles and embraces somewhat more than the southern half of the Cerbat Mountains. It contains Cerbat, Chloride, and other important camps.

The San Francisco district lies in the southwestern part of the area, in the Black Mountains. It extends from a point a few miles below Boundary Cone on the south about 25 miles northward to a point above Union Pass and Pyramid on the north, and from the east base of the range westward to Colorado River. On the north it has a width of about 15 miles and on the south of about 20 miles. It contains the Gold Road, Vivian, Silver Creek, Union Pass, Pyramid, and other important camps.

The Weaver district also lies in the Black Mountains, and may be regarded as extending from a point about opposite Chloride northward 30 miles or more beyond Eldorado Pass and the White Hills. It contains the Mocking Bird, Hall, Virginia, and other camps.

The White Hills district is situated in the western edge of the White Hills, opposite the north end of Weaver district, the Detrital Valley intervening. It is a small district, about 4 miles in length

[a] The relatively meager treatment of certain districts and properties is in most cases attributable to temporary suspension of operations, inaccessibility, or want of adequate information rather than to relative unimportance of the deposits.

and less than 3 miles in width, being confined to the granitic area shown on the map.

The Gold Basin district lies about 14 miles northeast of the White Hills district, in the western edge of the White Hills or Cerbat

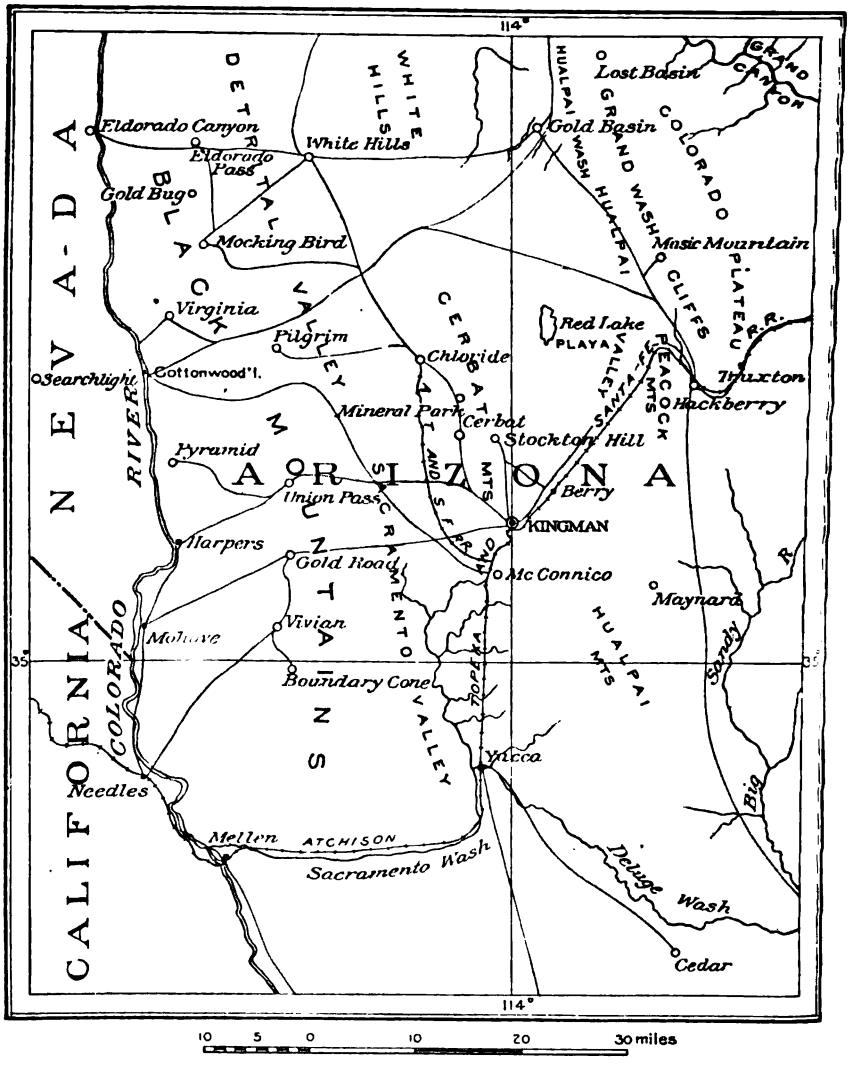


FIGURE 3.—Map showing mining camps in a part of western Arizona.

Range and west of Hualpai Wash. It consists of a somewhat irregular area about 5 miles in diameter.

The Lost Basin district lies northeast of the Gold Basin district, between Hualpai Wash on the west and Pierce Mill Canyon on the east. It extends from Colorado River southward to a point about 12

miles distant from Scanlon Ferry, embracing the Grand Wash Cliffs and adjacent country east of Hualpai Wash.

A part of the Greenwood district is situated in the southeastern portion of the area, principally in the Aquarius Mountains. It extends from Big Sandy Wash eastward beyond the limits of the area mapped and southward to Williams River.

The Maynard district, of whose extent little that is definite is known, embraces the Hualpai Mountains.

The Music Mountain district is situated toward the eastern edge of the area near its middle part, east of Hualpai Valley, and extends from the vicinity of Music Mountain, which lies 12 miles north of Hackberry, about 16 miles northwestward along the Grand Wash Cliffs, and from the base of the cliffs eastward a distance of several miles.

The Hackberry district is supposed to cover an indefinite area containing the deposits about Hackberry.

The Cedar Valley district lies along the western base of the Hualpai Mountains.

PRODUCTION OF MOHAVE COUNTY.

Although the early reports of the Director of the Mint contain many valuable notes on the mining industry of Mohave County, no detailed statistics for this area are available. The output since 1903, as ascertained by the United States Geological Survey, is as follows:

Production of Mohave County, Ariz., 1904–1907.[a]

Year.	Gold.		Silver.		Copper.		Lead.	
	Ounces.	Dollars.	Ounces.	Dollars.	Pounds.	Dollars.	Pounds.	Dollars.
1903	15,859	327,806	54,169	28,931				
1904	27,275	563,824	86,782	49,683	1,480	185	6,036	264
1905	26,272	543,090	73,536	44,416	30,399	4,742	112,266	5,277
1906	31,010	641,034	145,179	97,270	315,992	60,986	904,399	51,551
1907	28,307.90	585,383	80,897	53,392	601,210	120,242	1,229,654	65,171
1908	14,306.23	295,736	39,427	20,896	345,491	45,605	254,013	10,668

[a] Mineral Resources U. S., 1903–1908. In addition 30,666 pounds of zinc, having a value of $1,809, were reported in 1907, and 505,133 pounds, valued at $23,741, in 1908.

GENERAL CHARACTER OF THE DEPOSITS.

The metallic deposits of the ranges here described are chiefly fissure veins containing gold, silver, lead, copper, and zinc, quartz being the principal gangue mineral. They exhibit considerable diversity in character and occurrence, but naturally fall into two very distinct and sharply contrasted groups—(1) the veins of the Cerbat Range and (2) those of the Black Mountain Range. The nonmetallic mineral resources are less important and consist mainly of turquoise, cement rock, and building stones.

The veins of the Cerbat Range consist of quartz-filled fissures with a general northerly or northwesterly strike, which is also that of the

prevailing jointing of the country rock, and with commonly steep dip. The quartz contains pyrite, chalcopyrite, galena, zinc blende, and arsenopyrite, carrying principally silver but also gold. Free gold is scarce. Many of the veins are regular and persistent, with well-defined walls. They occur chiefly in pre-Cambrian granitic rocks, but are associated with post-Cambrian intrusions of granite porphyry and in places follow basic (lamprophyric) dikes. Many of the pay shoots coincide with intersections of fissures. Oxidation has altered the upper part to a depth ranging from 50 to 300 feet, and this oxidized zone changes to the primary ore within a vertical range of 10 to 40 feet. At the present time the sulphide ores are principally utilized, but the rich secondary ores, containing horn silver, native silver, and in some places ruby silver, furnished the bulk of the heavy production of the early days. The water level is found at 400 feet below the surface, but in some localities stands higher. The number of the deposits is very large and, owing to the fact that work was generally abandoned when the leaner primary ore was encountered, the area contains a large number of small mines which may be capable of future production. The deposition of these veins took place after the intrusion of the granite porphyry and the lamprophyric dikes and is probably an "after effect" of this igneous activity. The veins have suffered great erosion, and their mode of occurrence leads to the belief that they were deposited at comparatively great depths by hot waters.

The second group comprises the veins of the Black Mountains. These also are filled fissure veins with a general northerly or northwesterly strike and steep dip. The fissure filling is quartz, adularia, and calcite, and in many places there is evidence that the first two minerals have replaced the calcite, probably through the medium of hot solutions. (See Pl. II.) The values are almost exclusively in gold, which, as a rule, is very finely divided and can best be recovered by the cyanide process. The veins are fairly regular, but the walls are usually rough and broken and full of stringers from the main vein. The quartz filling contains many inclusions of the country rock. The veins cut through the great mass of Tertiary volcanic rocks which characterize the range, but undoubtedly continue in depth into the underlying pre-Cambrian granitic rocks. The most favorable ore horizon seems to be formed by the green chloritic andesite, and in the underlying older andesite the veins are barren. Profitable ore is, however, often found in the upper rhyolitic members of the series. The alteration of the country rock is of a propylitic character. The oxidation extends to a depth of 600 or 700 feet, and, as a rule, no sulphides are found. The water level is at least 700 feet below the surface. Compared with the veins of the Cerbat Range these deposits have suffered comparatively little erosion since

A.

B.

PSEUDOMORPHIC QUARTZ AFTER CALCITE.

Characteristic of veins in the San Francisco district, particularly of the Gold Road and Hardy veins.

their deposition. They bear evidence of having been formed rather close to the surface by hot waters which ascended through the lavas at the close of igneous activity.

MINERALOGY.

The region is not characterized by a great variety of minerals. The Black Mountains are especially poor in this respect.

The gangue minerals in the Cerbat Range consist of quartz, with some calcite, dolomitic carbonates, and siderite. Those of the Black Mountains are quartz, calcite, adularia, and pale-green fluorite. Limonite and hematite are common in both ranges as products of oxidation. The absence or scarcity of barite is remarkable.

The ore minerals of the Cerbat Range include silver, gold, pyrite, chalcopyrite, arsenopyrite, stibnite, galena, zinc blende, molybdenite, argentite, bornite, chalcocite, and ruby silver. Vanadinite and wolframite are known from the Gold Basin district. Among the oxidized minerals horn silver, cerusite, azurite, and malachite are the more important. The ore minerals of the Black Mountains are confined to native gold, pyrite, malachite, and a little argentite. Tellurides have lately been reported from several mines in the Gold Road, Vivian, and Union Pass districts, but none were found during the field work for the present report. Copper stains are present in places, indicating chalcopyrite or tetrahedrite. Vanadinite and galena are reported from the Gold Bug district.

CERBAT RANGE.

INTRODUCTION.

The principal districts in the Cerbat Range, named in order from north to south, are the Gold Basin, White Hills, Chloride, Mineral Park, Cerbat, Stockton Hill, McConnico, and Maynard. Of these the four most important are the Chloride, Mineral Park, Cerbat, and Stockton Hill districts, and these are often spoken of collectively as the Hualpai or Wallapai district. They are located in the middle part of the Cerbat Mountains, extending from a point just south of Stockton Hill and Cerbat to a point north of Chloride, a distance of about 12 miles, and they have certain features in common.

The rocks of this portion of the mountains are essentially of the pre-Cambrian complex, and consist of gray granite, gneissoid granite, and dark schists, including hornblende, mica, and garnet schists. They are flanked on the west in the Cerbat district by local areas of rhyolite and other Tertiary volcanic rocks. To the north, through Mineral Park and toward Chloride, they are intruded by distinctly younger masses of granite porphyry. Furthermore, they are locally

cut by dikes of pegmatite, aplitic granite, diabase, vogesite, minette, and rhyolite.

The deposits are well-defined fissure veins, of which there are two main sets, one striking about N. 10° to 30° W. and the other N. 45° to 70° W., usually with steep dips. According to Comstock [a] there is also a not generally recognized but important older latitudinal or east-west auriferous vein system, whose veins, usually not prominent or not apparent at the surface, have been encountered mainly in some of the deeper mines and have contributed handsomely toward the enrichment of the ores of these mines. The Elkhart and Tennessee mines at Chloride are given as examples. Veins of the same strike usually occur in two "conjugated systems"—that is, dipping in opposite directions, indicating that a compressive stress has originated the fissures. The dips are usually steep. The veins are more or less clearly associated with younger intrusions of granite porphyry, and some of them follow dikes of vogesite, minette, or aplite. The croppings, which are generally prominent, consist of dark reddish-brown quartz and altered country rock stained by the oxides of iron and manganese. The veins are straight and some are long. The walls are usually good and marked by soft gouge, although many veins are "frozen" to the walls. The gangue is quartz, in many places shattered and recemented by a later generation of calcite. Among the primary ores the most important are pyrite, chalcopyrite, arsenopyrite, galena, and zinc blende, more rarely molybdenite and stibnite. Silver and lead predominate in the Chloride, Mineral Park, and Stockton Hill districts; gold and silver in the Cerbat district. This primary ore is leaner in gold and silver than the oxidized ore, and many mines, notably in the Chloride and Mineral Park districts, which near the surface were silver mines, with increase in depth carried more lead, and at still greater depths seemed to become cupriferous. The so-called "copper belt" of the area extends from Mineral Park northwestward toward Chloride for a distance of several miles.

The water level is found at a maximum depth of 400 feet, but in some places lies considerably nearer the surface. In general the ores above the water level are oxidized, but the line between the two classes is not always sharply marked. In many places (e. g., in the Tennessee vein) galena, and locally, also, pyrite, appears near the surface in association with oxidized ores. In the Towne mine and a few others oxidized ores are found below water level, but not to any great depth, so far as known. The secondary or oxidized ores consist chiefly of native silver, probably also some native gold, horn-silver, and cerusite. Ruby silver and argentite are also present with oxidized ore, but do not seem to occupy any well-defined zone between the oxidized and primary ores.

[a] Comstock, Theodore B., Geology and vein phenomena of Arizona: Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 1044–1054.

Many of the ore shoots coincide with intersections or forking of veins. Good examples are mentioned in the description of the Pinkham, Elkhart, Rainbow, Pay Roll, and Tennessee mines.

CHLORIDE DISTRICT.

LOCATION.

The Chloride district, the most important in the Cerbat Range, is situated about 20 miles north-northwest from Kingman, in the northern part of the Hualpai district, near the western slope of the Cerbat Mountains. It is comprised in an irregular area about 6 miles in diameter. As shown on the accompanying map, the principal mining locations are disposed roughly in two broad, irregular belts, intersecting each other near their middle points, one, about a mile in width, extending from the Samoa mines, at the crest of the range on the east, for about 6 miles to the west, terminating in the foothills or adjacent part of the Sacramento Valley plain about 2 miles west of Chloride. Its western half parallels the base of the mountains, which here depart from their normal nearly north-south course and extend several miles to the west, and its eastern half lies between the crest and the base of the mountain range on its western slope. The other belt parallels the north-south base of the range and lies mainly in its lower slope and the adjacent part of the Sacramento Valley. It diminishes in width from about 2 miles on the south to less than a mile on the north.

Chloride, the shipping and distributing point of the district, is situated a trifle northwest of its center, at the northern terminus of a branch of the Atchison, Topeka and Santa Fe Railway, connecting with the main line at Kingman. It is favorably located at an altitude of 4,000 feet on an open gentle slope near the base of the mountains. It is also the distributing point for the Weaver, Minnesota, and White Hills districts and for Eldorado Canyon, Nevada.

HISTORY AND CONDITIONS.

Chloride, so named from the character of its rich silver ore, was the first settlement laid out in this part of the area. As a camp it dates from the early sixties, when the first mineral discoveries were made, and as a town from the early seventies. The decline in the price of silver affected the district unfavorably, of course, but it has continued fairly active up to the present time. In 1900 it is said to have had a population of 2,000. For the last four or five years the district has been quiet. Several of the more important mines, however, are in active operation and considerable work on a moderate scale is being done on a score or more properties of well-known merit.

The following are the depths reached by the principal mines:

Depths of mines in Chloride district.

Juno	600	Pinkham	230
Elkhart	500	Midnight	200
Tennessee	600	Altata	200
Schuylkill	500	Payroll	400
Minnesota-Connor	530	Mollie Gibson	200
Lucky Boy	400	Distaff	180
Samoan	300		

The early prospectors were several times driven out by the Indians and seven of them are said to have been killed. Owing to the prominent vein croppings, all the principal mines were located at about the same time.

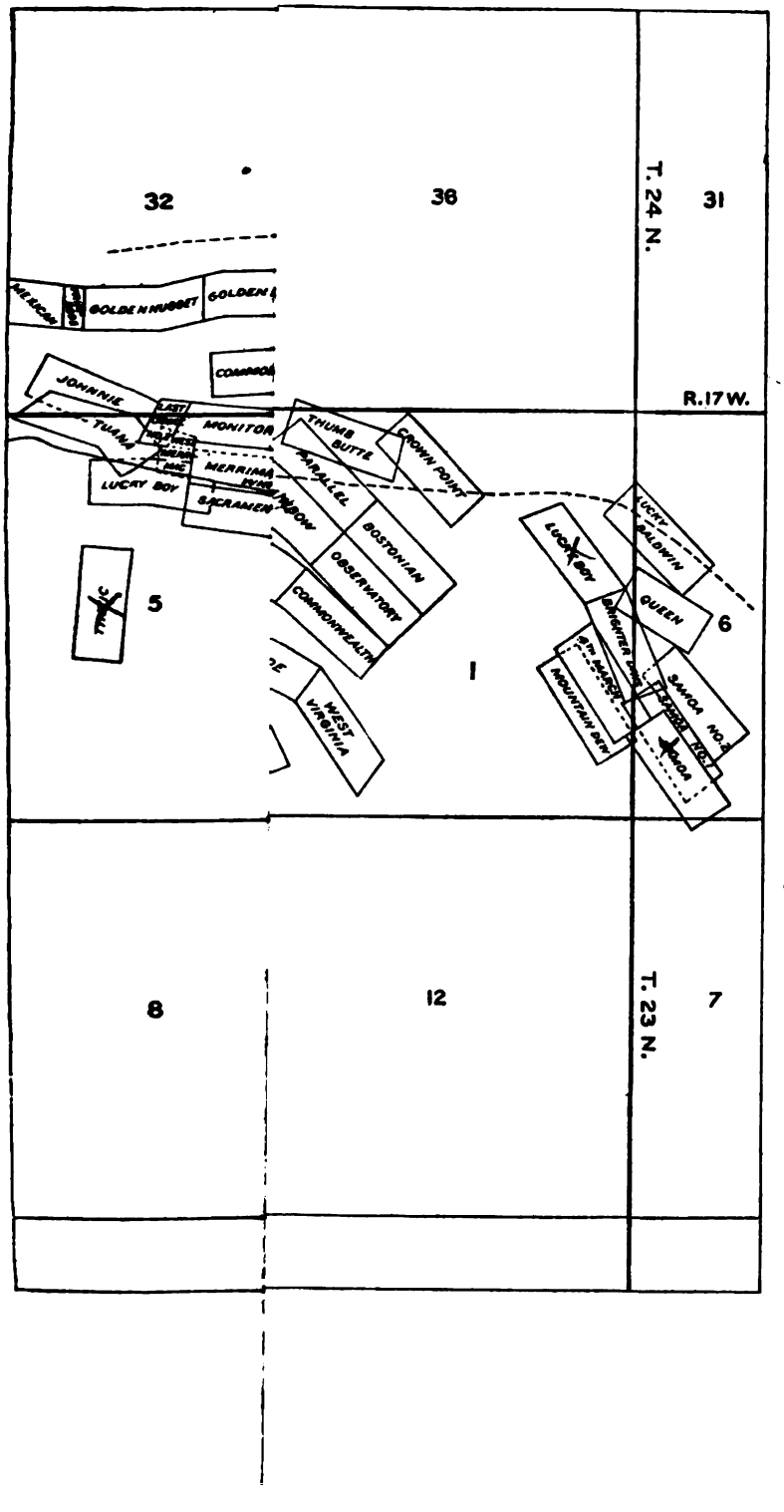
Among the first locations made were the mines now known as the Silver Hill properties, just southwest of Chloride, and the Golden Fleece, Tintic, Independence, and others. Some of the ores were of too low grade for shipment to San Francisco and to Swansea, England, but later, when a mill was built at Mineral Park, they were reduced there. Others, however, were so rich that when shipped abroad they netted their owners large sums. The district has produced a very large amount of lead and several million dollars' worth of gold and silver. It is not possible to obtain even approximate figures of the production. The lack of water has been one of the chief drawbacks of the camp, but with deep sinking plenty will be obtained.

Plate III is a map of the mining claims in this district, and Plate IV gives views showing the topography.

GEOLOGY.

The eastern part of the district is in part rugged, the topography being of the type produced by erosion and weathering of granite. In a distance of about 2 miles the surface descends from the altitude of 6,000 feet at the crest of the range to about 4,000 feet at its base, where it meets the plain of the Sacramento Valley. This plain is composed of detritus and wash derived from the range and contains deposits of caliche(?). (See p. 219.) The mountain slope is dissected by several main gulches, among which Samoa, Windmill, and Tennessee gulches are the chief. These drain southwestward into the Sacramento Valley. On the northwest the mountains are lower. Southward-sloping foothills, with no sharp line of demarcation, separate them from the adjacent plain of the valley.

The rocks are chiefly those of the pre-Cambrian complex. In the westward extension of the mountains, immediately north of Chloride, is an area of younger granitic rock, which is intruded into the pre-


32
36
31
T. 24 N.
R. 17 W.
GOLDEN NUGGET
JOHNNIE
TUANA
MONITOR
LUCKY BOY
SACRAMENTO
THUMB BUTTE
CROWN POINT
BOSTONIAN
OBSERVATORY
COMMONWEALTH
WEST VIRGINIA
LUCKY BOY
LUCKY BALDWIN
QUEEN
SAMOA
5
1
6
8
12
7
T. 23 N.

Cambrian, and at first glance is difficult to distinguish from the older granitic gneisses, especially as it also has a distinct schistosity. It is a medium-grained granitoid rock, much resembling the granite porphyry of the Mineral Park batholith. It breaks down easily and weathers greenish or yellowish brown, and seems to impart the latter color to about all but the upper portion of the front of the range from Chloride northward. It is moderately schistose in a north-south direction, the dip of the schistosity being vertical, and it is sliced by a northwesterly sheeting which dips 70° NE.

GENERAL CHARACTER OF DEPOSITS.

The deposits occur in two systems of well-defined fissure veins. One strikes a little west of north and stands nearly vertical, another

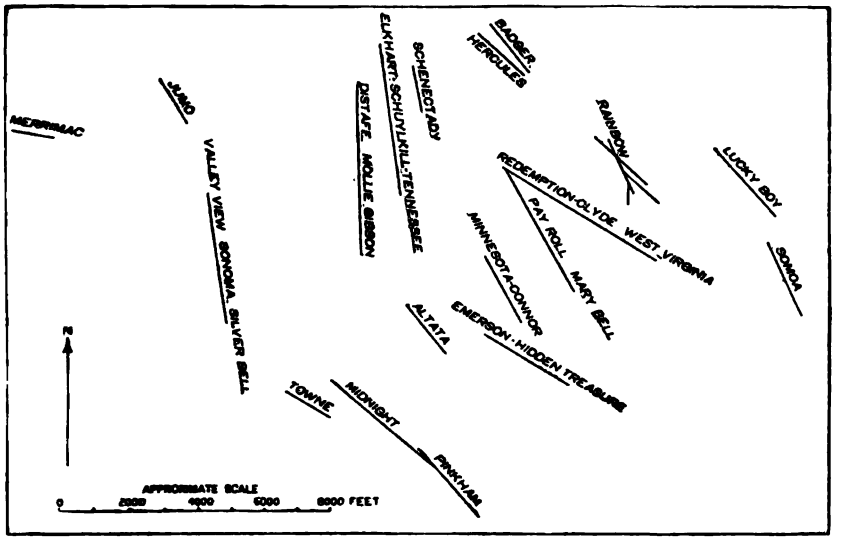


FIGURE 4.—Diagram showing trend and relative position of the principal veins in the Chloride district.

strikes about due northwest and dips steeply either to the northeast or to the southwest. (See fig. 4.) Many of the ore shoots are located at points where spurs or feeders join the vein in an oblique direction. The ores principally contain silver and lead with some gold and copper. The gangue is quartz with some calcite and other carbonates. The primary ore minerals include pyrite, chalcopyrite, arsenopyrite, galena, zinc blende, molybdenite, and probably bornite. The secondary minerals are silver, hornsilver, argentite, ruby silver, and chalcocite, together with various oxidized lead and copper minerals. In a reconnaissance report, like this one, only some of the more important properties can be described to convey an idea of the deposits and developments of the region.

TENNESSEE MINE.

The Tennessee mine is 1 mile east of Chloride, at the foot of the mountains, on the east side of Tennessee Wash, at an elevation of about 4,050 feet. (See Pl. V, *B*.) It is owned by the Tennessee Mining Company, of Chloride.

The Tennessee is an old mine and has been worked for more than fifteen years. It has produced hundreds of thousands of dollars in ore. Among the earliest owners were A. M. MacDuffee, and later Mr. Botsford, who held the property for eight or nine years and is still part owner with the present company, which took it over in 1906. For the six years ending in 1903 the Hualpai Mining and Development Company, with headquarters at Los Angeles, operated the mine and took out chiefly lead ore. For a long time during this period the production was a carload of concentrates a day, or sometimes 50 carloads a month, besides a large amount of high-grade ore that was constantly being shipped. From 1904 to the middle of 1905 the mill was shut down, but since then the present company has been running the mine and mill almost steadily, and the property is now being developed for handling on a larger scale.

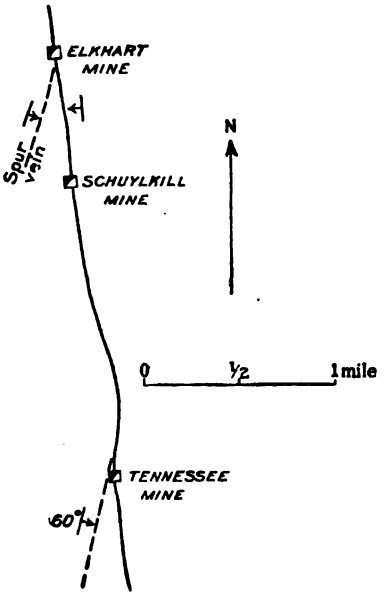


FIGURE 5.—Plan showing course of Tennessee vein.

The country rock at the mine is a gneiss with granite and schist occurring near by. The gneiss is composed chiefly of sericitized feldspar and crushed quartz with streaks of chlorite. The granite is a pinkish-gray medium-grained microcline rock, somewhat crushed, and contains very little biotite. The schist is the fine-grained, black, typical amphibolite variety and is composed essentially of brown hornblende, sharply defined feldspars, mostly triclinic, and a little pyroxene.

The mine is situated on the Tennessee vein (see fig. 5) and is developed by two inclined shafts and six levels. The shafts are located 280 feet apart. The main or northern shaft is 600 feet deep and the southern shaft 400 feet. The levels are spaced 100 feet apart vertically, the first level being 100 feet below the surface, as shown in the accompanying vertical section of underground workings

A. PART OF LAVA MESA SURROUNDING KINGMAN, LOOKING NORTHWEST FROM WEST SIDE OF TOWN.

B. CHLORIDE AND PART OF CERBAT RANGE, LOOKING EAST FROM SILVER HILL.

(fig. 6), which also shows the amount of drifting on the various levels.

The vein croppings, rising locally several feet above the surface, are reddish, brownish, yellowish, and blackish quartz and galena stained with iron and manganese. The vein is regarded as a part of the great lead-bearing "lode" on which the Schuylkill and Elkhart mines to the north are situated. At the surface the vein strikes N. 8° W. and dips about 68° E.

The main or north shaft starts on the vein, its slope at first coinciding with the dip of the vein. With increasing depth, however, the dip gradually diminishes until on the 400-foot level the vein lies 30 feet east of the shaft, and in the 200-foot drift on the 600-foot level the strike of the vein is N. 10° E. This change in strike, however, on this level may be occasioned by what seems to be a spur vein

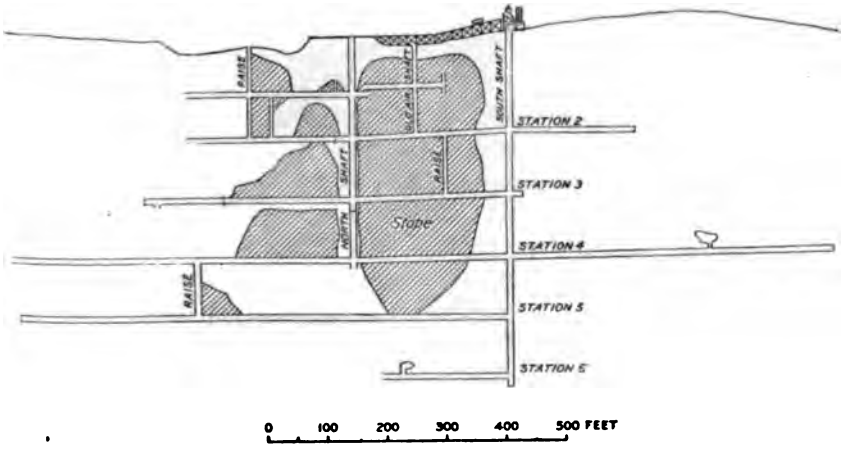


FIGURE 6.—Longitudinal section along Tennessee vein.

or feeder coming in from the west, as shown in figure 5, as there is a considerable body of rock, probably 5 or 6 feet in thickness, between the ore zone in the drift and that in the stope above, and as the structure in the crosscut from shaft to drift and main vein suggests the presence of such a spur vein which dips toward the main vein.

The walls for the most part are hard, smooth, and fairly regular. On the 600-foot level three systems of slickensides are shown, whose component direction indicates relative vein movement downward and northward at angles of about 40°. Slickensiding is also shown to a marked degree in some of the ore.

The Tennessee is a lead mine, and one of the most prominent lead-bearing properties of the Territory. The ore contains mainly galena, zinc blende, and pyrite, and also carries good silver values and some

gold and copper. Specimens collected from the 600-foot level consist of a medium to fine grained mixture of bright crystalline galena and dull resinous sphalerite in about equal amounts, and contain about 5 or 6 per cent of irregularly disseminated iron and copper pyrites. The galena locally exhibits an imperfectly banded structure, due to pressure.

The average run of mine ore, omitting the zinc, is about as follows: Lead, 20 to 70 per cent (concentrates, 75 per cent); silver, 8 ounces (concentrates, 25 ounces); gold, small amount; copper, some in deep part of mine, increasing in amount with depth.

Gold occurs only in small amount and is found in the pyrite. Of the total ore output about one-third is high-grade shipping ore; the remaining two-thirds is milled.

The mine has been productive from the surface down. From the ground between the surface and the 400-foot level thousands of tons of rich galena ore have been shipped to the smelter. The ore shoot had a horizontal extent of about 250 feet, and contained some bodies 15 feet in width. Extraction was easy with a small amount of timbering, but it is reported that owing to the extravagant management of the property the profits realized were small. There is said to be good ore still remaining in this part of the mine, but on account of caving of the stopes it will be difficult to extract.

On the 400-foot level a vein 21 feet thick, with 5 inches of solid galena, was mined for about 40 feet horizontally. From the fourth to the fifth level there was a decrease in the value of the ore, due to the predominance of zinc blende, but from the fifth to the sixth level galena increased to the proportion shown in the upper part of the mine.

The 500-foot level contained good ore for a distance of 800 feet, and the upraise from it showed 12½ feet of almost solid galena. In the 200-foot drift of the 600-foot level, toward the end of the drift, the vein showed about as follows: Good ore, with quartz coming in toward right, 2 feet 9 inches; milling quartz, 8 inches; fair ore, with bunches of quartz, 7 feet.

According to Comstock[a] the mine, about 1899, in its new workings encountered one of the buried older east-west auriferous veins or cross belts of mineralization, which increased the gold value of the mine product from $4 to $10 a ton.

No effort has ever been made to handle the zinc as a by-product, it being allowed to go into the tailings dump at the mill, which also contains values of the other metals, silver and gold. In addition, large bodies of good zinc ore, some 12 feet in width, on the 200-foot and 500-foot levels, have been left standing in the mine. The avail-

[a] Comstock, Theodore B., Geology and vein phenomena of Arizona: Trans. Am. Inst. Min. Eng., vol. 30, 1900, p. 1048.

A. ELKHART MINE AND MILL, LOOKING NORTHWEST.

B. TENNESSEE MINE AND MILL, LOOKING SOUTHEAST.

able tailings in the dump are estimated by H. L. McCarn at 12,000 tons, and they will concentrate about 60 per cent, or about 1 ton of zinc in 4 or 5, and will besides carry 8 to 10 per cent of lead and some silver and gold. Of zinc alone, by fine grinding and proper treatment, they are expected to yield about 300 tons of concentrates. There seems to be little doubt that the zinc, which heretofore has been regarded as a detriment, can be marketed at a good profit. In January, 1908, after the foregoing was written, Mr. McCarn informed the writer that the tailings were being worked over with jigs, tables, and electrostatic separators.

The most important of the surface improvements at the mine are a well-equipped steam concentrating mill, having a capacity of 100 tons in twenty-four hours, and two substantial steam hoists, that to the south having a capacity for a 1,000-foot shaft.

SCHUYLKILL MINE.

The Schuylkill mine, one of the oldest in the district, is about 1 mile northeast by east of Chloride, on a patented fractional claim adjoining the Tennessee on the north. It is on the west side of Tennessee Wash, and 100 feet above it, at an elevation of about 4,300 feet. It is owned by the Southwestern Mining and Smelting Company, a Pittsburg corporation.

The mine in early days was worked by Monroe Salisbury, who operated the Benson smelter, to which much of the ore was shipped. Later it was sold to the present company, which did the deep development work planned to extend to a depth of 1,000 feet, and is said to have blocked out much good ore ready for stoping when, about three years ago, work was suspended.

It is situated in alignment with the Tennessee and Elkhart mines and is supposed to be on the Tennessee vein (fig. 5); the country rock and ore are similar to those of the Tennessee mine. The vein here strikes N. 9° W. The large dump shows that much work has been done. The developments consist of a steam hoist, an excellent shaft 500 feet deep, two long crosscut tunnels, and considerable drifting and additional crosscutting. The mine has produced much good ore and has much more in sight reported to carry good copper and gold values. That from the surface workings was mostly of high grade. Rich silver-lead ore is also reported to occur on the 400-foot level, and on this and the lower levels are ores with native silver, running $100 a ton. The mine was closed at the time of the writer's visit.

ELKHART MINE.

The Elkhart mine (Pl. V, *A*) is situated a little more than a mile northeast of Chloride, west of Tennessee Wash, and adjoins the

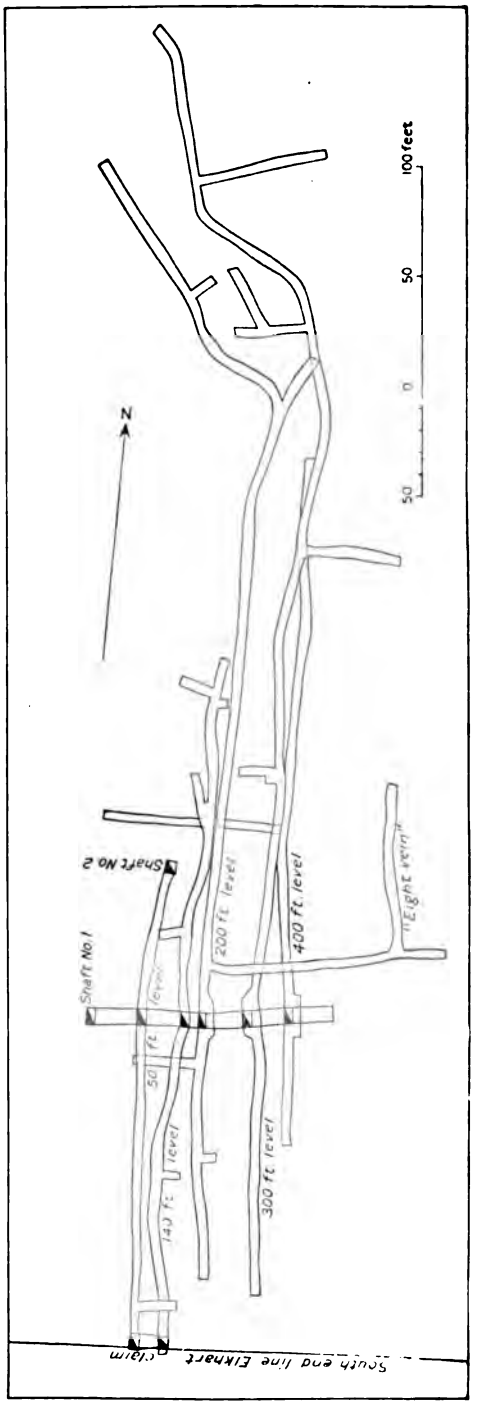


FIGURE 7.—Plan of Elkhart mine.

Schuylkill mine on the north. Its property embraces four claims, the Elkhart, Argyle, Dumferlin, and Bullion, as shown in figure 7.

The Elkhart is one of the older mines of the region. It was located in the early eighties and produced several thousand tons of rich ore from the surface down. Later it was worked by Ohio peopeople and still later sold to a Scotch company, of which Theodore Comstock was the general manager. He put up the mill and installed the machinery about 1895–96. In 1902 another company bought it from Mr. Comstock and later it passed into the hands of J. H. O'Neill, of Los Angeles. In 1906 it was acquired by the present company. The mill closed in April, 1906, but started later and ran until October 15. A large amount of money has been spent on the mine, for which it has returned but little. It is owned by a corporation of Glasgow and Los Angeles capitalists, with headquarters at Los Angeles. It is located on the northern part of the Tennessee or "big lead" vein, or a similar vein lying in its trend, and has associated with it one or two

parallel veins or supposed feeders or spurs. The country rock is pre-Cambrian granite and gneiss similar to that at the Tennessee mine. Some diabasic rock is present near by, but was not observed in association with the vein. The zone of oxidation extends to a depth of about 80 feet.

The mine is developed by shafts and levels. The main shaft is on the vein and is sunk to a depth of 500 feet; another is down 200 feet, and a third 80 feet. There are six levels, but they are somewhat irregular and there is reported to be about 400 feet of drifting on each level, not including numerous stopes and crosscuts. The principal surface equipments consist of a steam hoist with a capacity for a shaft 1,000 feet deep and a dry-crushing concentrator mill having a capacity of 100 tons in twenty-four hours. The mill is in good condition and formerly turned out a carload of concentrates a day. Both mine and mill are accessible by a good wagon road of easy grade.

The ore contains galena and carries gold and silver, the gold being contained mostly in the pyrite, as at the Tennessee mine; but the ore differs from that of the Tennessee mine in the absence or scarcity of zinc blende. The sulphide ore is reported to approximate as follows: Lead, 63 per cent; silver, 25 ounces per ton; gold, $10 per ton.

The ore is reported to be much the same in quality from the surface down, and to favor the hanging wall. The ore bodies are said to be 15 feet in width in some places.

According to Comstock[a] a parallel vein struck on the 200-foot level yielded $20 in gold to the ton, and on the same level prolonged northward a cross vein of similar type belonging to the old latitudinal series was worked, carrying ore plentifully sprinkled with yellow pyrites running well in gold, the gangue being entirely different from that of the main vein. This new vein is also present on the 300-foot level. On the 400-foot level white orthoclase feldspar dikes, which are probably aplite, are reported to be closely associated with the vein series to which it belongs.

In portions of the mine refractory clay or kaolin-like deposits of considerable extent, derived from kaolinization of the feldspar in the country rock, form the walls of the vein.

With the exception of some ore on the second level, the ore in sight is about all worked out down to the fourth level, and new ore bodies will have to be opened before the mine can produce much. The vein splits between the fourth and fifth levels, and above this split the ore, though principally lead, carries $8 to the ton in gold. The best ore

[a] Comstock, Theodore B., Geology and vein phenomena of Arizona: Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 1048–1049.

encountered thus far has been taken from the 500-foot level. Here the vein is reported to be 14 feet thick and to contain some very high-grade ore. The dumps, which are large, contain much ore and are all to be milled.

DISTAFF MINE.

Three-quarters of a mile east of Chloride and about one-fifth of a mile west of the Tennessee vein and about parallel with it, lies the Distaff-Mollie Gibson vein, on which are situated the Distaff, Mollie Gibson, and other properties.

The Distaff mine is located on a patented claim in the foothills just north of Tennessee Wash, at an elevation of 4,100 to 4,400 feet. It is owned by Charles E. Sherman, of Mineral Park. The country rock is the younger medium-grained granite described under "Geology" as characteristic of the region lying north of Chloride. Hornblende and mica schist also occur, notably on the east side of the claim. The granite is roughly schistose and the vein is about parallel with the schistosity. The vein strikes north with vertical dip and has a known extent of about a mile. It is but 2 or 3 feet in width and is easily worked, but pinches on the northern part of the Distaff ground.

The principal developments consist of about 2,000 feet of underground workings, including a 240-foot shaft and drifts. Recent shipments of what was formerly considered low-grade ore from the old dumps of the Distaff are reported to have netted several hundred dollars per carload. The production has been about $50,000, the ore being chiefly chloride or horn silver, with much native silver occurring in slabs or chunks many pounds in weight in the deeper part of the workings.

MOLLIE GIBSON MINE.

The Mollie Gibson is situated south of the Distaff and beyond Chloride Wash, the Bullion-Beck claim intervening. It is on the same vein as the Distaff. It is credited with developments 200 feet in depth and with having produced considerable lead-silver ore, some being of high grade.

HERCULES MINE.

The Hercules is a small mine, situated about 2 miles northeast of Chloride and about one-half mile east of Tennessee Wash, at an elevation of about 4,700 feet. It is close to the wagon road leading to the Lucky Boy and Samoa mines.

The Hercules was discovered about 1899 and held by Comstock & Ferguson until 1903. They drove a 60-foot tunnel from the canyon side and sunk four shafts to the depth of 20 feet, with no material results. In 1903 F. H. Kraft, the present manager and part owner

of the property, sunk a little deeper and struck good $30 ore, and the mine has been a steady though small producer ever since.

The country rock is the usual pre-Cambrian gneiss. The vein is 25 to 30 feet in thickness. It trends N. 54° W. and dips about 70° SW., with porphyritic granitoid gneiss on the hanging wall and black hornblende-mica schist on the foot wall. A neighboring vein trends N. 80° W. and dips 80° N. It occurs in the dark foliated schist, and the mine is probably on a chimney or ore body enriched by the intersection of this vein with the Hercules.

The principal developments are a 90-foot shaft sunk on the vein and some drifting, notably on the 50-foot level. The bottom of the shaft shows a pay shoot of very good ore 1½ feet thick. The mine yields a plentiful supply of excellent potable water. The ore is galena, running high in silver and containing good values in gold.

BADGER MINE.

Two miles northeast of Chloride and one-eighth mile north of the Hercules mine, on what is known as the Badger ground, occurs a large 20-foot vein known as the "Big vein." It strikes N. 40° W. and dips 80° SW. It has produced considerable ore. Tests from surface pits sunk on it show $16 ore, of which $12 is in gold. In a canyon one-eighth mile east of the Hercules the vein is cut by a close sheeting or cleavage structure trending N. 80° E.

At about 250 feet northeast of the "Big vein" and parallel with it, but dipping 80° NE., lies the well-known Badger vein. It has been mined to a considerable extent at several points to the northwest and has produced considerable ore.

Among the properties situated on it are the Badger group and the Badger and Woodchuck mines, located on eastern tributaries of Tennessee Wash. The two latter, owned by S. L. Chadwick, have produced considerable rich lead ore, which occurs in large bodies, but some of the ore is said to contain much zinc. The Badger group property is reported to have produced several hundred tons of good ore, chiefly in gold and silver, from a 300-foot tunnel 150 feet deep at the face.

EMPIRE MINE.

The Empire mine is situated about 2 miles north-northeast of Chloride, in a northeast gulch of Tennessee Wash, on a large vein which is supposed to be the northwestward extension of the Badger vein. It is one of the oldest and first patented properties in the district. It is developed principally by a shaft 200 feet deep. The values are principally in silver, which is very soft and very rich, and the yield has been good from the surface down. The production has been about $70,000. The mine was owned by William Raymond, one

of the discoverers of Pioche, and was worked by lessees with good profit. Later E. F. Thompson sank the shaft to greater depth and shipped ore of good grade.

PAY ROLL MINE.

The Pay Roll mine is about 1½ miles east of Chloride, near the middle of the west slope of the Cerbat Range. It is situated on Pay Roll Gulch near its head, at an elevation of about 4,400 feet, whence the surface rises steeply to about 5,200 feet in Rainbow Mountain on the northeast. The mine is approached by a good wagon road of easy grade.

The property, aggregating 40 acres, consists of two claims, known as the Pay Roll and Black Prince quartz. It is owned by Mrs. Mary Murphy, of Kingman, and Judge J. J. Hawkins, of Prescott. It was located in March, 1887, by J. W. Murphy.

The country rock consists of the usual pre-Cambrian crystalline schists, with granitoid rock predominating in the hanging wall and schist on the foot-wall side. A diabase dike is locally associated with the vein, which is cut off on the northwest by a raised fault block of black hornblende schist. In the gulch just below the mine the schists are cut by dikes of relatively young light-colored garnet-bearing aplitic granite.

The principal development work, all on the Pay Roll claim, consists of three shafts, aggregating about 500 feet in depth, over 600 feet of tunnels, about 400 feet of drifts, and some crosscuts and stopes. Shaft No. 1, the main working shaft, sunk off the vein, is 225 feet deep, and contains water in the sump. Shafts Nos. 2 and 3 are sunk on the vein to depths of 100 and 60 feet, respectively. The main drift is about 500 feet in length and the main crosscut tunnel about 130 feet. Where the latter intersects the vein a winze about 50 feet deep is sunk on the vein.

The mine is situated on the Pay Roll vein or lode, which strikes about N. 30° W. and dips steeply to the northeast; the structure in the adjacent rocks trends about N. 40° W., with the dip approximately vertical. The Pay Roll is one of the large veins in the Chloride region. As shown by its persistent croppings it has a horizontal extent of nearly a mile, but is reported to be somewhat broken in the bottom of the mine. It varies from 6 to nearly 100 feet in thickness, 10 feet being perhaps a fair average, and contains in places a fair grade of concentrating ore. The gangue is mainly quartz, and the vein is in places separated from the wall rock by a thick sheet of argillaceous or talcose gouge.

Near the mine, as shown in figure 4, the vein is joined by the Redemption Clyde vein, which probably enriches the Pay Roll ore shoots.

The ore in the persistent pay shoots consists of lead carbonates and galena, with some pyrite and chalcopyrite; it contains both gold and silver. The total production of the mine was not learned, but it is reported to include many carloads of rich shipping ore that run about $80 a ton, mostly in gold, derived principally from the surface workings, excellent values being found in the south shaft. So far as can be judged at present the deposit is a good-sized body of low-grade ore.

REDEMPTION MINE.

The Redemption mine, also known as the Ferguson, is a new property situated 2 miles east of Chloride and half a mile east of the Pay Roll mine. It is working on the Redemption Clyde vein, which lies east of the Pay Roll vein and joins that vein at the Pay Roll mine. The Redemption Clyde vein strikes N. 60° W. and dips 85° NE., and is known to have an extent on the surface equal to the length of at least four claims. Where opened on the Redemption property it attains an elevation of about 5,000 feet. Like the Pay Roll vein, it lies in the pre-Cambrian crystalline schists. It is opened by tunnels and winzes. The vein is about 4 feet thick, and the ore shoot is about 18 inches thick. The ore contains chalcopyrite in quartz and carries about 8 per cent of copper, 1 to 2 ounces of silver to the ton, and some gold. The production amounts to 200 tons of ore.

LUCKY BOY MINE.

The Lucky Boy mine is about 3 miles east of Chloride and about a mile east of the Redemption mine. It is near the crest of the Cerbat Range, at an elevation of about 5,750 feet, in the head of a gulch which is tributary to Windmill Wash. The property embraces four claims, the Lucky Boy, Brighter Days, Queen, and Baldwin. The total output is said to have had a value of about $150,000.

The Lucky Boy mine is an old property, located in 1892. It has been producing more or less all along and has been operated steadily for the last seven years. For some time it was owned by the Scott Lucky Boy Consolidated Mining Company, of Norfolk, Va., and was leased and worked by a company composed of Kingman men, Fred Stull being superintendent. Early in 1907 it was reported that the property had just been sold to an English company. In 1908 it was worked only on a small scale by lessees.

The principal rock is a medium-grained biotite granite, in which biotite, quartz, orthoclase, and much oligoclase are the essential minerals. This rock may possibly be of post-Cambrian age. It is intruded by a light-colored, fine-grained granite porphyry.

The mine is worked by shafts, crosscuts, tunnels, drifts, and stopes, the underground workings aggregating somewhat more than 4,000

feet. The developments consist essentially of five or six levels spaced 50 feet apart, with 500 to 600 feet of drifting on each level. The main shaft is 300 feet in depth. The shafts are equipped with gasoline hoist and a pump.

There are two principal veins, which strike north-northwest and dip about vertically. They are parallel and are 64 feet apart. They range from 3 inches to 6 feet in width in shipping ore, a width of a foot being an average, and $100 a ton an average value for the ore. The veins are said to be regular in character and the ore fairly constant in value. Under the microscope a section of the ore shows native silver, silver chloride, pyrite, and quartz. The ore in the front or southeast vein runs 3 ounces of gold and 125 ounces of silver to the ton; that from the "back" vein 5 ounces of gold and 80 ounces of silver. The superintendent, Mr. Stull, states that in the lower part of the mine there is a heavy, brassy-looking sulphide ore whose assay values in carload lots are 5 ounces of gold and 130 to 140 ounces of silver to the ton.

In their southeastward extension the veins pass to the northeast of the Samoa mine and do not occur on the Samoa claims, but if driven far enough the Samoa workings will cut them in the depths of the mountain.

RAINBOW MINE.[a]

The Rainbow mining property, comprising nine claims, is situated about 2½ miles east of Chloride, at an elevation of about 5,500 feet, near the summit of the Cerbat Range. All the claims contain veins of more or less promise.

The production is about $75,000, the bulk of which—about $60,000—was made prior to 1891 by chloriders. Since then, according to Mr. MacDuffee, who became interested in the property about that time, the shipments, mostly for the years 1891 to 1901 inclusive, aggregated about 210 tons, with an average value of $72.55 a ton, amounting to over $15,000.

The Rainbow mine was discovered and located in 1883 by Erin Sherman and was worked intermittently until 1890. Recently it has been taken over and is now being operated by the Rainbow Mining Company, of Chloride.

The country rock is the pre-Cambrian gray gneissoid granite considerably altered and silicified along the veins and containing some of the usual acidic and basic intrusives. The principal workings are those of the Rainbow mine, near the middle of the group, and of the Rainbow claim, on the Rainbow vein.

The Rainbow vein is not large, but occupies a definite walled fissure extending throughout the length of the claim. It strikes

[a] In the preparation of this statement on the Rainbow mine the writer has freely drawn on an unpublished report by H. L. McCarn.

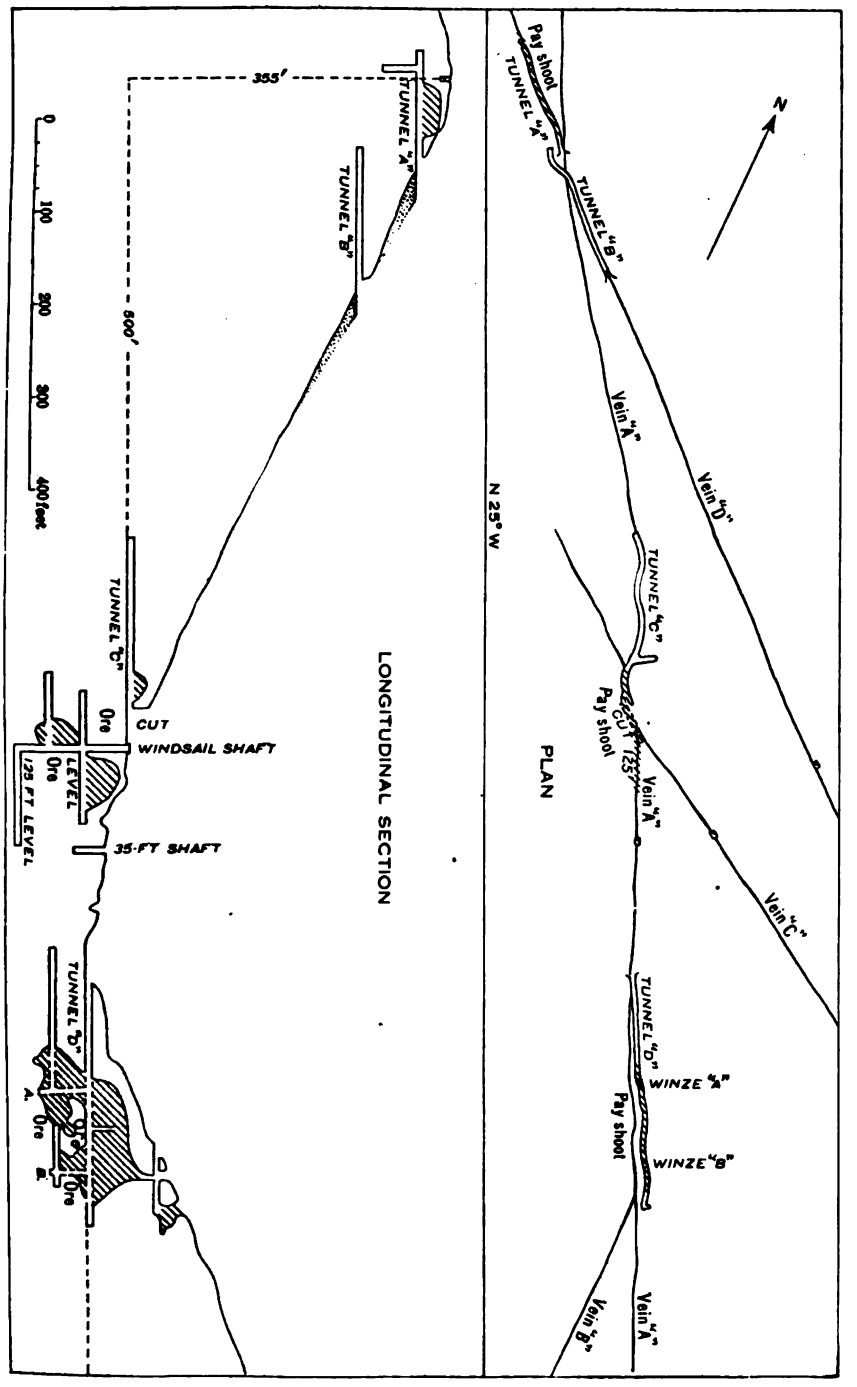


FIGURE 8.—Plan and longitudinal section of Rainbow mine.

north-northwest with vertical dip and is joined by several spur veins or feeders which come in at acute angles and materially enrich the ore shoots at junction. The ore streaks are persistent and easily followed and range from 6 inches to 3 feet in width, while in some parts of the old stopes there is said to have been 6 feet of solid ore, presumably situated where the vein is joined by feeders.

The principal developments (see fig. 8) are the Windsail shaft, 125 feet deep, and about 1,000 feet of drifts, crosscuts, stopes, etc., but owing to caving below the 50-foot level the lower part of the mine is not now accessible. No stoping has been done below the 100-foot level, and but little below the 50-foot. A wagon road of heavy grade crosses the northern part of the group and connects with the mine, about a mile distant, by a trail over which supplies and ore are now packed on burros.

Even the shallow depths reached by the mine show ore of good grade. Sulphide ore begins at a depth of about 100 feet below the surface. There are three main ore shoots, known as the North, Windsail, and South shoots. The North shoot is situated near the north end of the claim, 300 feet above the main part of the mine. It was extensively worked by chloriders in early times, and so far as known is a silver-lead shoot, containing fair values in gold.

The Windsail ore shoot is at the principal workings of the mine, near the middle of the claim. Here a streak of ore consisting of quartz and carbonate of lead of about equal width, and aggregating 12 to 15 inches in width, is exposed for 25 feet. Assays of the carbonate collected along a length of 25 feet show values of 2½ ounces of gold and 2 ounces of silver to the ton, and by estimate 12 per cent of lead—a total value of about $70 a ton. In the 50-foot level north the streak is pinched and lean, being disturbed by a dike, but it carries 4 inches of $40 ore, and just below this level excellent ore ($60 to $70) is said to have been taken from a streak 6 to 18 inches thick. A small stope above the 50-foot level south is reported to have produced more than 100 tons of $60 to $75 ore, and the block of virgin ground extending from this stope down to the 125-foot level, where a foot or more of good ore occurs in the roof of the drift, should produce a considerable quantity of good-grade ore.

The South ore shoot, situated 200 feet from the Windsail and worked by tunnel D, seems to be the principal ore shoot on the property and furnished the bulk of the ore shipped in early days. It is developed by a 260-foot drift, stopes, and winzes, and the ore has been mostly worked out down to the sulphide zone. Remaining portions of oxidized ore show good gold, silver, and lead values. The sulphide ore in the south end of the workings varies from 6 to 15 inches in width and averages about $42 to the ton in gold and silver. The sulphide ore in general is closely but not sharply banded

and finer grained toward the outer sides of the shoot, and coarser and more imperfectly banded inwardly. The microscopic section shows the ore consist essentially of pyrite, arsenopyrite, galena, and quartz. The ore shoot has an average width of about 12 inches of clean ore and a length of 150 feet along the shoot. There is considerable low-grade ore in the filling of the old stopes.

The average of about forty-five assays made from various parts of the Rainbow workings is reported as follows: Gold, about 2 ounces; silver, about 20 ounces; lead, about $5 (12 per cent); or an average value of about $65 a ton. The gold amounts to about three-fourths of the value.

Nearly all the other eight claims of the Rainbow group have veins of more or less promise, but on most of them but little work has been done. Considerable work, however, was done on the Old Timer years ago, when only high-grade ore would pay to work, and it is reported that a large quantity of such ore was shipped. There is a 15-inch shoot of good ore in the bottom of the 70-foot shaft, and ore carrying over $30 a ton in gold, silver, and lead now lies on the dumps. The Lindgren-Kemp is also a large fissure vein with definite walls, yielding assays of $6 to $25 a ton.

SAMOA MINE.

Location.—The Samoa mine is 3½ miles east by about half a mile south of Chloride, just north of Cherum Peak and about one-third of a mile south of the Lucky Boy mine. It lies at an elevation of about 5,900 feet, in the steep crestal slope of the Cerbat Range, at the head of a gulch which drains westward into Samoa Wash.

History and production.—The Samoa is one of the early locations and for many years has been the most active and constant producer of good-grade gold and silver ore in the district. The property comprises a group of four claims and a fraction, the Samoa, Samoa No. 1, Samoa No. 2, Fourth of March, and Mountain Dew. The property is owned by the Chloride Gold Mining Company, with headquarters at Pueblo, Colo.

The total production of the Samoa mine has been about $180,000. Approximately $70,000 was produced in early times, the remainder being obtained by the present management under Leonard Hoffman, which took effect in November, 1903. The mine has a record of being a steady producer. The present output is about 90 tons a month. The ore is shipped principally to the Needles smelter. Advices received early in 1908 report that the mine was then being worked on a small scale only by lessees.

Geology.—The vein is contained in the pre-Cambrian granitoid series; the predominating gray or dark-gray granitic rock is much

the same as that at the Lucky Boy mine. A distinct sheeting trends about north and south and dips at about 80° E.

The series is intruded by a large dike of fine-grained, schistose microcline granite, which a short distance below the mine along the trail is in turn cut by a 100-foot rhyolite dike trending northward toward the Lucky Boy mine.

Veins and ore.—There are six parallel veins which strike about N. 10° W. and stand nearly vertical or dip steeply to the east at angles of about 80°. Named in consecutive order, beginning on the east, they are vein No. 1 or Samoa No. 1; vein No. 1½; vein No. 2 or Samoa No. 2; vein No. 3; Fourth of March or Samoa vein (on which are located the Fourth of March and Samoa claims); vein No. 3½ or "Blind" vein; vein No. 4 or Mountain Dew. Vein No. 3½ does not, like all the other veins, outcrop at the surface, but was encountered in driving the crosscut tunnel. Nos. 1 and 2 are situated 551 feet apart and Nos. 2 and 3 are 138 feet apart.

The principal producing vein, the one on which nearly all the work has been done, is No. 3, the Fourth of March. Its average thickness is about 4 feet, and the ore shoot is up to 30 inches wide. The ore holds to the foot wall and is overlain by several inches to 1 foot of gouge or altered granite. The ore contains pyrite, galena, and zinc blende in quartz gangue; occasionally a little molybdenum is found in cross veinlets of spar. There is no copper. The principal value, however, is in the gold and silver contained in the sulphides. The ore now shipped, as shown by the smelter return sheets for 1903 to 1906, inclusive, runs about as follows: Gold, 1½ ounces per ton; silver, 15 ounces per ton; lead, 8 per cent; and zinc, 5 to 8 per cent.

The levels on this vein have been considerably extended since the field work for this paper was done. The most noteworthy feature of the ore is its constancy in good gold values. Some specimens show portions of the ore, especially the zinc blende, heavily coated with secondary enrichment or growth of the black silver sulphide, which, at 600 feet below the surface, seems to speak well for the mine. Some specimens also show considerable native silver. The first ore in shipping quantities was taken from tunnel level No. 1. The ore shoot at this point was about 65 feet long, and in tunnel level No. 2 the same shoot is reported to have had an extent of 400 feet.

The other veins and their ore are in most respects similar to No. 3. As yet but little more than development work has been done on them. Veins Nos. 1, 2, 3½, and 4 are leased to the Arizona Birmingham [Alabama] Gold Mining Company, which is now drifting on vein No. 1. This vein, thought by some to be probably one of the Lucky Boy veins, has produced some ore. When visited by the writer early in February, 1907, a new "strike" had just been made on this vein

on the 200-foot level, where the breast of the drift 80 feet south of the crosscut tunnel showed 20 inches of clean, good-looking ore.

Developments.—The principal developments consist of three tunnels, 350, 900, and 1,200 feet in length, a main working shaft 335 feet deep on vein No. 3, and various drifts and stopes mostly along this vein north and south of the main shaft. There are over 3,000 feet of underground workings on vein No. 3 alone. It has three levels spaced 100 feet apart vertically. Tunnel No. 1 is 140 feet above tunnel No. 2, which is 50 feet above the first, or 100-foot level, and runs southeast. Tunnel No. 3 is a 1,200-foot crosscut tunnel in the plane of the second level; it runs N. 75° E., strikes the main producing vein 350 feet in from the entrance, at a point a few feet north of the shaft, and extends a few feet beyond vein No. 1. On the first level the vein is drifted on for 300 feet to the north and 650 feet to the south; on the second level, 300 feet north and 434 feet south.

A large amount of ore has been stoped and shipped from vein No. 3 from the ground immediately above tunnel No. 2, and from the vicinity of the shaft just above the first level. Present shipments are from the second and third levels. On the third level but little stoping has been done, and most of the ground between the second and third levels still remains intact. The ore on the whole is opened for a length of more than 800 feet along the vein.

Two plants well equipped with gasoline engines are located at the collar of the main shaft and the entrance of the crosscut tunnel. A wagon road connects the mine with the railroad at Chloride, but as yet the ore is packed to the railroad more directly on burros. Thirty men were employed in 1907.

The Samoa mine is undoubtedly a promising property, but although it seems in all respects to have been honestly, and for the most part, ably managed, and although the workings have been in ore all the time, so far as could be learned, it has not paid much more than expenses. It is well to note that the mine as a whole is rather a low-grade than a high-grade property, and that therefore the ore should be handled with a view to the greatest economy. The support and operation of a large pack train entails in itself a very heavy expense. Furthermore, the mine has never had an underground survey. Up to the present time the work has been carried on without plats, plans, or records of any kind, a very unusual procedure for so large a mine and one with such a system of veins.

Recent reports state that the Samoa and Lucky Boy mines are to be worked jointly on a large scale through a main tunnel opening on Lucky Boy ground.

MINNESOTA-CONNOR MINE.

Location.—The Minnesota-Connor mine, one of the more important properties of the district, is about 1¾ miles southeast of Chloride

and half a mile south of the Pay Roll mine, at an elevation of about 4,400 feet. It lies at the head of an open gulch which drains southwestward into Sacramento Valley. It is reached by good wagon roads of easy grade from the northwest and the southwest.

History and ownership.—The property is owned by the Philadelphia and Arizona Mining Company, of Philadelphia, to which it was sold by John Barry about 1902. It consists of two claims, the Minnesota and the Connor, joining each other end on. The property was located in the early eighties, since which time it has been a good producer, having yielded several hundred thousand dollars' worth of rich ore. In the early days the surface ores were worked by chloriders with handsome returns. Later the mine was leased to Messrs. Kelley and McKennon, under whom also it was a prolific producer. During the last few years the property has been leased to a new organization, the Lehigh-Arizona Mining Company.

Vein and ore.—The country rock is the usual pre-Cambrian complex, which here consists mainly of pressed microcline-biotite schist, hornblende schist, gneiss, and syenite. It is cut by dikes of vogesite or kersantite, which locally occur on either wall, by dikes of pale pinkish pegmatite or aplite, and by seams of epidote one-eighth to one-quarter inch thick.

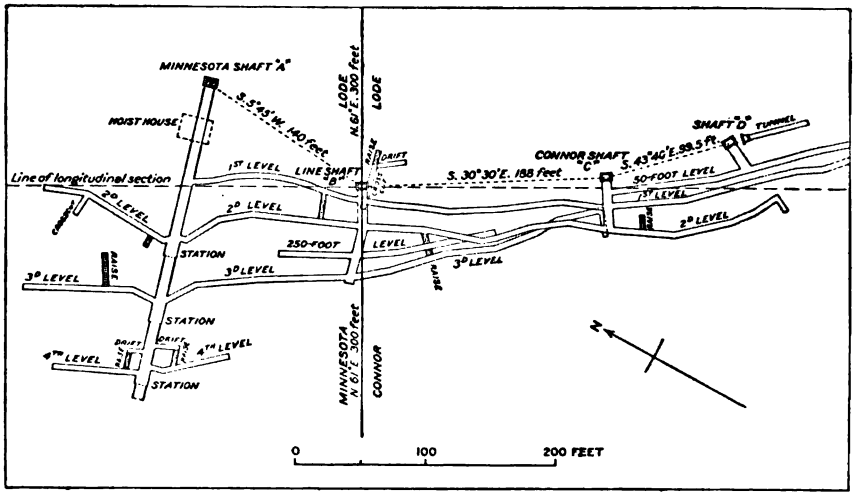


FIGURE 9.—Plan of Minnesota-Connor lode.

The vein strikes N. 30° to 50° W. and dips 60° to 80° SW. It is known to extend through a horizontal distance of 2,400 feet and varies from 5 to 20 feet in width. Where exposed on the surface and in the shallow shaft southeast of the mill it stands about vertical and is 5 feet in width, but it is reported to flatten and widen as it

goes down and in the deeper part of the mine it has in places a width of 20 feet of good ore.

The gangue is quartz, with some calcite, which locally seems to replace the quartz. The ore contains pyrite and arsenopyrite, as well as some chalcopyrite. The principal value is in silver, which in part is in the form of ruby silver, but the ore also contains some gold. Part of it is very rich, some large bodies running $200 or more to the ton. The production is reported to be about $100,000.

The property is developed to the maximum depth of 570 feet by four shafts and four levels, containing about 2,500 feet of drifts and other work approximately as shown in figure 9. The principal equipments are a very complete mill and hoists.

Owing to suspension of operations and the presence of water, the mine was not accessible at the time of visit, except the Connor shaft, northeast of the main workings. Here on the 50-foot level fair bodies of rich ore were found for a distance of 360 feet to the southeast of the shaft.

ALTATA MINE.

The Altata mine, one of the principal copper mines and one of the first mines worked in the district, is situated at the base of the mountains about 2 miles southeast of Chloride and about 100 feet above it and is easy of access. It is owned by the Altata Mining Company, of Chicago, and is steadily producing at a moderate rate.

The mine is developed principally by a main shaft and drifts to the depth of 180 feet. A large dump shows that considerable work has been done. The production is reported to have been about $200,000.

The country rock is pre-Cambrian schist, striking N. 23° E. with vertical dip. The vein strikes N. 40° W. and dips about 75° NE. Surface exposures indicate that it is not more than 2 or 3 feet thick, but it is reported to widen downward and to have contained a large body of good-grade ore near the surface, and also a similar one extending from the 130-foot level to a point below the 160-foot level.

The ore contains copper and silver in a quartz gangue, the copper occurring chiefly as bornite and being locally enriched by secondary chalcocite. Smelter returns show 32 carloads of the ore shipped some years ago to have averaged about $100 a ton, of which 20 per cent was copper and the rest silver. In the crosscut in the bottom of the mine a new vein, 20 feet thick, has recently been encountered with an 18-inch ore shoot on the hanging wall and a 24-inch shoot on the foot wall. The assay value of the ore varies from $12 to $15 a ton in gold, silver, and copper, and some similar ore is scattered across the intervening width of the vein.

EMERSON AND OTHER MINES.

The Emerson mine is nearly 3 miles southeast of Chloride and about 400 feet above it, in the lower slope of the range. The property comprises five adjoining claims. It is owned by Stephen Smith and Henry Schafer, of Chloride, and is producing on a small scale.

The topography is rough. The country rock is the pre-Cambrian complex. The vein is one of the strongest of the camp. It dips northeast at angles of about 77°. It is well defined and is reported to extend to the crest of the range, about 2 miles distant on the southeast. It is held by some to be the northwest extension of the Hidden Treasure vein and has the same characteristics. It is from 5 to 15 feet in width, 3 to 8 feet of which is mainly fresh hard quartz. The vein has been opened to a depth of about 200 feet, and three levels have been turned.

The valuable metal is gold associated with pyrite and chalcopyrite in a quartz gangue. The ore is ideal for concentrating and much of it is good grade shipping ore. The values are reported to continue the same in the sulphide zone as in the oxidized zone. An ore shoot 2 feet thick is said to average about $80 a ton.

In the vicinity of the Emerson mine are several other smaller properties, of which the most important are the Hidden Treasure, New Jersey, Manzanita, Good Road, and Mother Lode. The ores in these properties usually contain gold, silver, pyrite and galena.

The Hidden Treasure is reported to contain five parallel veins ranging from 2 to 8 feet in width, and is developed by several shafts, of which the deepest is 118 feet deep. The ore contains gold, silver, and lead, of which select lots run 3 ounces of gold and 10 ounces of silver to the ton, and 10 per cent of lead.

The New Jersey mine is developed by a 90-foot shaft and about 500 feet of drift. The vein strikes northwest. The face of the drift shows 16 inches of ore, with pyrite and galena, carrying good gold and silver values. Some of the ore has been shipped to the smelter.

The Manzanita property is developed by a shaft and is equipped with a steam hoist. The vein dips steeply southwest.

The Gladstone property lies about a mile southeast of the Emerson, in the first gulch south of Samoa Gulch. It is developed by tunnels and winzes and is bonded to persons who have recently begun deep sinking. The ore contains pyrite and chalcopyrite carrying gold and silver values.

TOWNE MINE.

Location.—The Towne mine is 1¼ miles south of Chloride and about half a mile from the base of the mountains, on open ground in the Sacramento Valley.

History.—The mine is reported to be the first property located in the Chloride district. It received favorable comment in the Wheeler Survey report as early as 1872. It was discovered and located as the "Porter and Black Smoke" in 1871, and immediately became a producer. It was first owned by a Mr. Parker, who took out considerable money, and later by W. H. Palmer, under whom it was known as the "Sunlight." Still later it was owned by F. H. McLaughlin until 1882, and since then it has been owned and operated by John Barry, a well-known pioneer and leading mining man of western Arizona. The mine is now producing in a small way. It is developed principally by six shafts, four levels, drifts, and stopes, the deepest shaft, No. 2, being 230 feet deep, and most of the others between 100 and 200 feet. The workings have a horizontal extent of about 400 feet. The mine has a considerable influx of water.

The production during the first decade of the mine's existence, which is reported to be considerable, was not learned. The production from 1882 to 1906 was about $1,000,000, and was derived mostly from the 70-foot level. The ore has been shipped to Socorro, Denver, Pueblo, and El Paso; it is now shipped to Needles.

Geology.—The country rock is pre-Cambrian amphibolite schist and biotite gneiss, with some bodies of pegmatite. The schistosity strikes N. 30° E. and dips steeply to the east. The rock is cut by vogesite dikes, which trend northwesterly. The one at the mine is about 200 feet in width.

Mineral deposits.—The mineral deposits consist of two veins about 40 feet apart. They lie nearly parallel and in places seem to be separated by the vogesite dike rock only. The one on the north, which is known as the "old vein," strikes N. 77° W. The other, and at present more important one, known as the "new vein," is the one now worked. It strikes N. 70° W. and dips about 70° NNE. It is about 3 feet in average and 8 feet in maximum width and is wider in the deeper part of the mine than near the surface. It is well defined and easily worked. The hanging wall is principally biotite gneiss and the foot wall the vogesite dike rock. Pronounced slickensides between the walls and the vein descend steeply east-southeast. At a point 108 feet east of shaft No. 3 the veins are abruptly cut off by a small fault, beyond which, so far as the work extends, the dip flattens to about 45°.

The gangue is quartz, much of which is shattered and pinched and the ore contains principally silver and gold, with some pyrite, zinc blende, and galena. It runs about $200 a ton, with nearly 200 ounces of silver, and 5 to 7 ounces of gold. Smelter returns show some carload lots averaging as high as 7 ounces of gold and 600 ounces of silver to the ton. Some of the richest ore shoots occurred on

the 100-foot level and east of shaft No. 3, where the ore averaged 10.4 ounces of gold and 240 ounces of silver, and some assays, it is stated, gave returns as high as 18 ounces of gold.

The ore shoots range from 3 to 18 inches in width, with an average of about 5 inches, depending on the quartz. The ore occurs almost wholly on the foot-wall or vogesite-dike side of the vein, with usually a small seam of talc intervening.

PINKHAM MINE.

The Pinkham mine (Pl. VI, *A*), perhaps the most important copper mine of the region, is about 2 miles southeast of Chloride and about three-fourths mile east of the Towne mine. It is located in the open border of Sacramento Valley, near the foot of the range, at about the same elevation as Chloride.

The mine was located about 1896, but production began only recently. It is owned by Skee Brothers, of Santa Monica, Cal. It was recently bonded to the Union Smelting and Refining Company, of Los Angeles. The company began operations in March, 1906, and installed a 60-ton oil smelter and a coke smelter, both of which, it is stated, owing to improper processes and fluxes, failed to successfully extract the ore. The matte, however, is reported to have averaged 40 per cent of copper from 2½ per cent raw ore.

The company then proceeded to mine and ship the ore, which ran about $300 per car, and the property is now producing on a moderate scale. The mine is developed principally by a main 240-foot shaft and five levels, aggregating about 1,200 feet of underground work. It contains some water. The levels are located at about 50, 85, 110, 140, and 230 feet below the surface. The work is distributed approximately as shown in figure 10, which has been prepared and kindly furnished by Mr. H. L. McCarn.

The country rock is the pre-Cambrian complex, and it is intruded by microcline granite and diabase dikes near by. The vein strikes N. 40° W., but varies as shown in figure 10, and dips at angles ranging from 65° SW. to vertical. It is reported to be the same vein that starts from the east side of Congress " ledge " in Mineral Park Wash, near Mineral Park, nearly 2 miles distant, and to be traceable by its croppings all the way from this point to the Pinkham mine.

The croppings consist of rust-brown, iron-stained, crushed and recemented quartz and silicified rock about 3 feet in width, rising 2 or 3 feet above the surface. Underground the vein is on the average about 12 feet in width, with a local maximum width of about 30 feet. It is composed principally of a gangue of crushed quartz and crushed and altered granite, with locally some irregular streaked or banded ore.

A. PINKHAM MINE AND SLOPE OF SACRAMENTO VALLEY, LOOKING SOUTH-SOUTHWEST.

B. MIDNIGHT MINE, LOOKING NORTHEAST.

The ore contains principally copper and silver, with some gold and a little zinc. In the oxidized zone near the surface carbonates and oxides prevail, but in the deeper part of the mine sulphide ore begins, with a quartz and calcite gangue. This ore is said to average about 3 per cent of copper and 18 ounces of silver per ton and contains about 8 per cent of lime. The ore minerals are pyrite and chalcopyrite, with some bornite. Some of the ore shows a secondary growth or enrichment of chalcocite.

The ore occurs in lenses or elongated kidneys and in chimneys. The principal source of the ore thus far mined is a large chimney extending from a point near the shaft westward on the first and

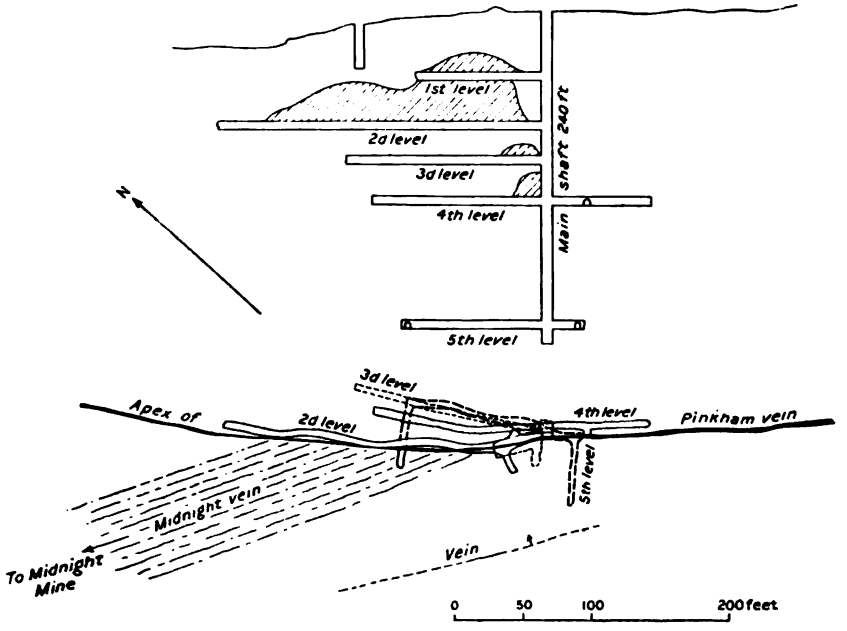


FIGURE 10.—Plan and longitudinal section of the Pinkham vein.

second levels. It has a width of 14 feet. A sample taken across it, including everything, is reported to have given a total assay value of $24 a ton. Much ore of this kind appears to be in sight here. The enlargement and enrichment of the vein at this locality seem to be due to the Midnight vein coming in obliquely from the northwest, as shown in figure 10.

Where work was being done on the second or 85-foot level at the time of the writer's visit in 1906, the stopes showed a width of 3½ feet of rich ore, mostly chalcocite and bornite, extending horizontally for a distance of about 40 feet, and the face of the drift at about 200 feet north of the shaft showed 5 feet of good ore, some of which averaged about $100 a ton and showed secondary deposition or enrich-

ment of chalcocite on the pyrite and chalcopyrite. The vein at this point stands about vertical or dips very steeply northeast instead of southwest, its normal direction.

Later a fine body of high-grade copper sulphide ore, 18 to 24 inches in width, was opened in extending the drift northwestward on the fourth or 140-foot level. This ore averaged about 9 per cent of copper and 60 ounces of silver to the ton.

On the fifth or 230-foot level, which is practically the bottom of the mine, the vein dips about 70° SW. and is from 4 to 6 feet in width. The face of the drift, 100 feet northwest of the shaft, shows a width of 8 feet with the foot wall not yet in sight. Here the vein consists of coarsely streaked or irregularly banded ore, crushed quartz, and altered country rock, all pretty soft and containing 4 to 6 inch gouge seams.

South of the shaft the vein is mineralized for a width of 20 feet or more, and at the end of a 40-foot crosscut into the hanging wall there is a good looking small vein 1½ feet wide, which dips steeply to the northeast.

MIDNIGHT MINE.

The claim of the Midnight mine practically joins that of the Pinkham mine on the northwest, as shown in Plate III, and, like the Pinkham, is situated on open, gently sloping ground. (See Pl. VI, *B*.) The mine was discovered prior to 1866. The original owner was a pioneer named Carpenter, who in early times hauled some of the ore to the Mineral Park mill. Later the mine was owned by Heimrods, McDuffee & Gilleland, and still later by the partners Darius Brown, Robert Gibson, James Boyd, and John St. Charles. Finally, about 1898, John St. Charles and his brother Keene became the sole owners. They alone have done most of the development, and have shipped ore from the deeper levels.

The mine is developed principally by inclined shafts, drifts, and crosscuts, and is equipped with a gasoline hoist. The main shaft is 200 feet deep, and the drifts, crosscuts, and stopes aggregate several hundred feet of workings.

The same country rocks prevail as in the Pinkham vein, being principally pressed and crushed microcline-biotite granite, and this is also intruded by the same classes of diabase and granitic dikes in or near the mine, the diabase apparently being the later of the intrusives (fig. 11). The vein or lode is less well defined than the vein in the Pinkham mine. As shown in figure 10, it strikes in general about N. 65° W. and on the southeast seems to join the Pinkham vein. It has a width of 50 to 75 feet and contains much low-grade ore. As seen in the mine, it contains two main veins or ore bodies, of which the principal or south one strikes about northwest and dips irregu-

larly southwest at angles of 35° or more. The second vein strikes about N. 80° W. and dips steeply to the north.

A large amount of good ore is shown in the mine, but it contains much zinc, and considerable disturbance, including lateral faulting, has taken place, by reason of which further development is needed before the structure can be worked out. The ore contains silver, copper, gold, zinc, and iron. The silver occurs mostly in chalcopyrite, the rule being the more chalcopyrite the more silver. Some bornite is present. The gold is found principally in the pyrite. The zinc blende, though more or less mixed with the ore, occurs also in a relatively pure 3-inch shoot on the hanging wall in the northeastern part of the mine.

For some years past the mine has been shipping copper ore in a small way. This ore was rich and averaged about $1,500 a ton, but some of it contained 5 or 6 per cent more of zinc than the 10 per cent allowed by the smelters and was accordingly penalized. It seems probable that by the use of a suitable magnetic separator the zinc could be extracted and profitably marketed as zinc ore. In certain parts of the mine the ore contains 30 to 40 per cent of zinc, and is so low in other values that it will be shipped as zinc ore. A recent carload shipment of the ore averaged 66 ounces in silver and $2.50 in gold to the ton and 4.5 per cent of copper. Under the present management the mine has produced about 300 tons of ore, with a total value of about $7,000. The ore is reported to mill about 5 to 1.

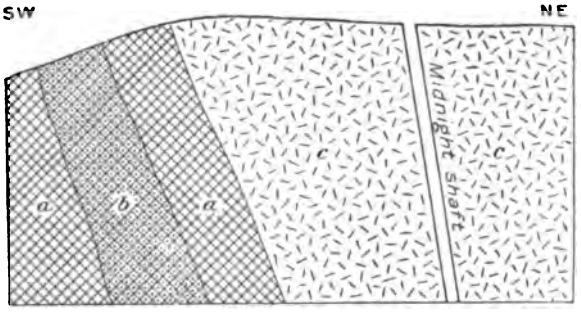


FIGURE 11.—Diagram showing intrusions near Midnight shaft. *a*, Aplite; *b*, diabase, intrusive into aplite; *c*, granite.

SILVER HILL VEIN.

The Silver Hill vein is located on Silver Hill, a prominent elongated ridge just southwest of Chloride and rising about 150 feet above it. It extends southward nearly to the railroad station. The ridge trends about north and south, is about three-fourths of a mile long and one-eighth of a mile broad, and is composed almost wholly of dark amphibolite schist. A coarse granititic rock appears to be intruded in its western base, and it is locally traversed by dikes and stringers of the garnet-bearing aplitic granite and also by a coarse pegmatitic granite. The schist dips about 60° E. and is cut by a well-marked sheeting that dips about 35° W.

As shown by openings and croppings, the northern or main half of the ridge is traversed longitudinally just west of the crest by a well-marked vein or mineral zone, varying from 2 to 12 feet or more in width, whose croppings, hardly rising above the surface, consist of brownish, yellowish, or greenish stained quartz, and seemingly altered dike material, which in places is calcareous and brecciated. The foot wall consists of a bowldery or brecciated schist.

The vein strikes N. 7° W. and dips steeply east. It is opened at intervals along its extent by five or six inclined shafts, some of which attain a maximum depth of about 100 feet. The work was done mostly in pioneer times, as this was among the first veins worked in the district. The ore contains silver, lead, and gold and is reported to carry about 2 ounces of gold to the ton, but the principal production is stated to be a small amount of lead.

JUNO MINE.

The Juno mine is situated in the low foothills about three-fourths of a mile northwest of Chloride, and is supposed to be located on the northward continuation of the Silver Hill vein. It is one of the early locations and was worked intermittently until about five years ago, when the shaft caved in, since which time work has been suspended. It was developed to the depth of 600 feet and equipped with a steam hoist. It is owned by E. T. Lloyd and B. Miller.

The vein dips steeply to the northeast. It is said to have been large on the surface, and the ore on the whole is rich. The surface ore was treated by a leaching process. The mine is stated to have produced much good ore and is regarded as a good property. Several operators have derived good returns from it.

MERRIMAC MINE.

The Merrimac mine is situated about a mile west of Chloride, at the border of the foothills and the Sacramento Valley, on open ground. It is one of the early discoveries and is owned by the Minnesota-Connor Mining Company. It is developed to the depth of about 200 feet and is equipped with a hoist and concentrating mill, but has not been worked for some time. The concentrating tables have been removed from the mill, and the mine has the appearance of being abandoned.

The country rock is pre-Cambrian coarse porphyritic gneiss. It is traversed by numerous veins or stringers, which are opened by prospect pits and shallow workings. The vein on which the mine is located seems to trend about N. 60° W. and dips to the northeast. The gangue is hard quartz and the ore contains silver and gold associated with pyrite. Much of the ore is banded and hard. The

high-grade ore contains ruby silver with a small amount of gold. Difficulty is said to have been encountered in concentrating the low-grade ore. A large dump shows that much work has been done, and the mine is reported to have produced considerable good ore.

TUCKAHOE MINE.

The Tuckahoe mine, one of the early discoveries, is 1½ miles west of Chloride, on the main road to White Hills. It is located on open ground, like the Merrimac mine, at an elevation of about 3,900 feet and in about the same class of porphyritic pre-Cambrian granite, which a few hundred yards east of the mine is cut by a diabase dike. Some basalt débris is strewn upon the surface. The mine is developed by a 45° inclined shaft, 200 feet deep, sunk upon the vein, and is equipped with a windmill hoist. It is owned by John Barry.

The vein strikes about N. 25° W. and dips about 45° NE. Certain irregularities suggest that other associated veins or stringers may be present near by, as at the Merrimac mine. The gangue is hard quartz and a mixture of quartz and country rock, locally crushed and recemented in the form of a breccia or conglomeratic mass, with many of the rock fragments rounded or pebble-shaped. The ore contains principally silver values, but some gold and galena are also present, all in association with iron pyrite.

The mine has produced a considerable amount of good ore. It was worked some years ago by the hyposulphite leaching process and $10,000 is said to have been extracted in one year. The latest ore shipped is stated to have averaged $10 in gold and 75 ounces of silver to the ton, and 17 per cent of lead. The mine is now producing in a small way.

TINTIC MINE.

The Tintic mine is situated on open ground in Sacramento Valley, about 1½ miles west of Chloride and half a mile south of the Tuckahoe mine. It is said to be located on a nearly flat-lying vein, which dips to the northeast and is from 2 to 10 feet thick. Water is said to be encountered at a depth of 40 feet below the surface.

The ore values are almost exclusively in gold and are said to average about $150 a ton in carload lots. The production is reported to be many thousand dollars, most of which has been obtained within a distance of about 200 feet, extending horizontally along the vein.

OTHER MINES.

Besides the mines already described there are in the district probably a score or more of small mines and promising veins, such as the Century group, Bobby Burns, Roger Boy, Goldback, and others, concerning whose locations and character data adequate for descrip-

tion are not at hand. Some of these properties are reported to be developed to the depth of 200 feet or more and contain several hundred feet of drift.

MINERAL PARK DISTRICT.

GENERAL DESCRIPTION.

The Mineral Park district practically joins the Chloride district on the south. Mineral Park, the main camp and post-office, situated near the middle of the district at an elevation of 4,200 feet, is about 4 miles from Chloride. The district trends about north and south, with a length of about 5 miles, which but slightly exceeds its width. It lies mainly in a basin several miles in diameter between the elevations of 4,000 and 5,000 feet. Some of the deposits on the north, however, extend nearly to the top of Cherum Peak, whose elevation is about 7,000 feet. The topography surrounding the basin is mountainous, but for the most part not rugged. The drainage issues westward into Sacramento Valley, mainly through Mineral Park Wash. Open groves of scrub pine and cedar occur in the hills.

The principal supply point is Chloride, but ore and heavy freight are hauled direct to the railroad, 3 miles to the west. The first location made in the district was the Mayflower, in 1870. It was soon followed by the Keystone No. 1 and No. 2, and then by the Lone Star. Considerable ore was soon taken out and shipped to the Selby smelter at San Francisco at a cost for freight of $125 a ton. Some ore was also freighted eastward by oxen over the old government trail to New Mexico.

The Keystone mill, which is still standing, was built at a reported cost of $125,000 and started in 1876. Operations continued more or less actively until the price of silver began to decline in 1882, and during that time the district was one of the heaviest producers and shippers of rich gold and silver ore in the Cerbat Mountains. Since 1882, however, the production has been small, only a few of the mines being worked. One of the reasons seems to be the fact that many of the mines are owned by the original locators or men who have not the means to work them below water level, which in a greater portion of the district is encountered at a comparatively shallow depth. Several springs occur in the district.

The Keystone mill contains a crusher, five 1,000-pound stamps, with pans, a Bruckner revolving reverberatory furnace, and a 25-horsepower engine. In the early days it received most of the ore from the Cerbat Mountain region, including the Chloride, Cerbat, and Stockton Hill camps. The treatment charges are reported to have been very heavy, but, on the other hand, the operators found it difficult to extract the values from the ore.

GEOLOGY.

The country rock is the pre-Cambrian complex, and comprises gneisses and schists as well as gneissoid granite. The structure or schistosity strikes a little west of north, with nearly vertical dip. The complex is extensively intruded or broken through by masses of the later, probably post-Carboniferous coarse granite porphyry, and is cut by dikes of rhyolite, diabase, and minette. In the northeastern part of the district, on the slope of the range between Mineral Park and Cherum Peak, the schistosity and sheeting in the pre-Cambrian rocks trend N. 65° E., with vertical dip, and a secondary sheeting trends N. 20° W. and dips about 80° E.

The district on the whole is well mineralized, and its mineralization seems to be largely due to the porphyry. Remote from the intrusive masses this granite porphyry is locally associated with the veins as dikes. It forms the upper part of a prominent foothill or knob on the northwest, known as Niggerhead. It also constitutes a considerable portion of the mountains on the opposite side of the wash, to the south, and extends interruptedly throughout the greater portion of the basin eastward for 1½ miles into the slope of the range. Its structure or jointing, which also penetrates the underlying pre-Cambrian rocks, is well shown across the northern part of Mineral Park district. It dips westward at angles of about 35°.

ORE DEPOSITS.

The deposits contain gold, silver, lead, and copper in fissure veins or lodes, some of which are unusually large. The strike of the veins is N. 37° to 60° W., and the dip is steep to the northeast or the southwest. There are also a few cross veins striking northeast or east and west. The gangue is quartz, with pyrite, chalcopyrite, arsenopyrite, galena, and zinc blende as the principal ore minerals. Especially in the upper levels there are also secondary argentite, native silver, copper, horn silver, and cerusite. The oxidized zone does not extend to a great depth.

The mines, numbering about twenty, are small, few of them exceeding 300 feet in depth or containing more than 1,000 feet of underground work. The principal ones are the Rural, Buckeye, Ark, Queen Bee, Tyler, Keystone, Fairchild, Metallic, Accident, Lady Bug, Standard, and Golden Star. They are nearly all reached by wagon road. The most important producers at present are the Keystone, Tyler, and Queen Bee.

KEYSTONE MINE.

The Keystone mine is situated on open ground about one-fourth of a mile east of Mineral Park and about 200 feet higher. It was located

by Charles E. Sherman, a well-known pioneer, in 1870. Its surface ores were very rich and carried high values in gold as well as in silver, by reason of which it soon became the first important producer, its ores being shipped to Swansea, Wales. It was later worked by the Mineral Park Mining Company, and the ore was locally milled in the Keystone mill. Later it was owned by James Uncapher, of Mineral Park, by whom it was sold to the present owner, the Keystone Mining Company, of Greensburg, Pa. The production of the mine to date is reported to be about $50,000.

The mine is developed mainly by a shaft 450 feet deep and 500 feet of drifts, mostly down to the 150-foot level, above which the greater part of the ore is worked out. The principal surface equipments are a steam hoist and a 5-stamp mill.

The principal rock at the mine is the granite porphyry. There are two veins. The vein on which the mine is located strikes N. 60° W. and dips about 80° NE. The gangue is quartz in which the ore shoots occur mainly in the form of lenticular streaks about a foot thick. The ore contains pyrite, chalcopyrite, and zinc blende, with silver and some gold. The silver is present as argentite, in part. The better grade of ore runs about 200 ounces of silver to the ton, 2½ per cent of copper, 8 to 10 per cent of zinc, and 12 per cent of iron. Toward the outside of the lenses it is irregularly and closely banded. It is richest where the vein pinches. Elsewhere it may be distributed in a thickness of 3 feet of quartz gangue, but it is good concentrating ore and is said to average $12 to $15 a ton, and by reason of its low grade should be milled on the ground. Some of the ore, however, runs considerably higher. That averaging $20 or more a ton is now shipped to the Humboldt smelter. None lower than $20 ore is now handled. The present rate of output is about 20 tons a month.

About 50 feet northeast of the vein on which the mine is situated and lying about parallel with it is a second or smaller vein, which looks well and whose ore is reported to be nearly all of shipping grade.

TYLER MINE.

The Tyler mine is situated in the southeastern part of the district, 2¾ miles southeast of Mineral Park, near the summit of the range, on a steep northeastern slope, at an elevation of about 5,300 feet, or about 1,200 feet above Mineral Park. A good wagon road extends nearly to the mine, with which connection is made by a good trail of easy grade. The mine was discovered by Stephen A. Tyler, the owner, in 1901. It began to ship ore in 1905, but only necessary assessment work is now done.

The mine is developed mainly by two crosscut tunnels and drifts, mostly situated within a vertical range of 100 feet, principally on the Gold Eagle claim.

The country rock is pre-Cambrian medium-grained gneissoid biotite granite. The vein strikes N. 37° W. and dips about 75° SW., into the mountains. It has a width of about 40 feet and seems to consist mainly of an altered and partly replaced crushed and recemented aplitic dike. The entire width is claimed to be low-grade ore, but the values occur chiefly in the first 6 or 7 feet of the hanging-wall side of the dike and are best near its contact with the granite. The hanging wall also carries 6 inches to 2 feet of slickensided gouge, between which and the country rock occurs quartz breccia containing some ore.

The mine produces gold-silver-lead ore. The principal ore minerals consist of galena and cerusite. The last carload shipped at the time of the writer's visit averaged gold 3.16 ounces to the ton, silver 8 ounces to the ton, and lead 17.5 per cent. At last accounts the mine is reported to be sold to a Los Angeles company.

LADY BUG MINE.

The Lady Bug, an old mine, is about half a mile southeast of the Tyler mine, close to the Tyler camp, at an elevation of about 5,000 feet. It was located in 1886 by Isaac Conkey, the owner, now residing at Mineral Park. It is developed principally by a 63-foot shaft, 100 or more feet of drifts, and a number of surface openings on the vein.

The country rock is pre-Cambrian biotite granite, the same as at the Tyler mine, and it is to a considerable extent intruded by the granite porphyry of Mineral Park. The vein is reported to be 7 to 8 feet thick. It lies nearly parallel with the Tyler vein, but differs from it in being composed of a gangue which is mainly quartz. The ore contains principally silver chloride and gold with a little galena. A considerable portion of the ore mined is reported to have averaged $300 to $500 a ton. The production is reported to be $6,000.

RURAL AND BUCKEYE MINES.

The Rural and Buckeye mines are in the northeastern part of the district, 1½ miles northeast of Mineral Park, near the south base of Cherum Peak, at an elevation of about 5,000 feet. They are reached by wagon road. They are situated but a few hundred feet apart on the same vein, the Rural being on the west and the Buckeye on the east side of the same gulch. The Rural is owned by E. F. Thompson, of Kingman, and the Buckeye by C. E. Lovett and others, of Denver, Colo.

The Rural is developed principally by a 200-foot shaft, about 100 feet of drift, and a winze. The drift extends westward, its face being about 110 feet distant from the shaft. The shaft contains some water. The Buckeye is developed principally by about 750 feet of drift, extending in an easterly direction. Toward the face of the drift the vein is faulted off to the northeast by a lateral throw of about 75 feet.

The country rock is medium-grained gneissoid biotite granite and associated schist. It is intruded by dikes of granite porphyry. The deposits occur in a fissure vein which is 2 to 4 feet in width in the Rural and attains a maximum of 8 feet in the Buckeye. In the Rural it dips about 80° S. and in the Buckeye about 70° N. In both mines it is associated with a dike of the granite porphyry, masses of which occur to the northeast near by. The gangue is quartz and is generally "frozen" to the walls. It shows ore shoots ranging from 4 to 20 feet in width, which consist mostly of pyrite and chalcopyrite, with parallel streaks of arsenopyrite, black oxide of manganese, gray chert, and quartz, the quartz being more prominent in the Buckeye than in the Rural mine.

The ore contains silver, gold, and copper, with high silver and gold values. The display of ores from these mines, containing masses of solid silver and beautiful specimens of wire silver, is said to have been awarded the silver medal at the Louisiana Purchase Exposition.

The production, exact figures of which are not available, is reported to mount well into thousands of dollars in silver and gold, and much good ore is said to be available in the mines.

WINDY POINT MINE.

The Windy Point mine is in the northeastern part of the district, about a mile northeast of Mineral Park, on open sloping or hilly ground, at an elevation of about 4,800 feet. It is owned by the Arizona Gold Mining and Metallurgical Company, with headquarters at Kingman. It is developed mainly by a 105-foot shaft and a small amount of drift. The shaft starts in gneiss, but soon enters the granite. The mine is newly equipped with a gasoline hoist and electric drills.

The country rock is the pre-Cambrian gneissoid biotite granite and black amphibolite schist. The granite is less dark and micaceous than at the Rural and Buckeye mines. The structure or sheeting strikes N. 85° W. and dips about 75° S. Both the granite and the schist are more or less sericitized and impregnated with pyrite and

vrite near the vein. About 50 feet from the vein, on its

foot-wall side, the country rocks are cut by a peculiar greenish-gray porphyritic dike rock, which seems to be minette, and is apparently younger than the intrusive granite porphyry. The latter is also present in outcrops near by, and some of it was recognized in the dump débris derived from the mine.

The deposits occur in a fissure vein which strikes N. 42° W. and dips about 77° NE. It is 2 to 4 feet wide, and the pay streak or ore shoot ranges from 3 to 24 inches in width and favors the hanging-wall side. The values are in silver, gold, and copper. The minerals are principally pyrite, arsenopyrite, and chalcopyrite. The last shipment of the ore is reported to have averaged 3 ounces of gold and 486 ounces of silver to the ton and 2½ per cent of copper.

GOLDEN STAR MINE.

The Golden Star (formerly Lone Star) mine is in the northeastern part of the district, about a mile northeast of Mineral Park, a short distance below the Windy Point mine, at an elevation of about 4,700 feet. It is situated on open, sloping, somewhat hilly ground. The mine was located in 1870 and soon became an important producer of rich ore. It continued to be prominent till 1902, when the ore seems to have fallen off in grade. The mine is now dismantled of all surface equipments. Its output during much of this period is said to have been the largest in the region.

The mine was first owned by W. F. Grounds, now of Hackberry, who took out much rich ore. It was later owned by Fred Harter and Isaac Conkey, of Mineral Park. The present owners, besides Mr. Conkey, are W. G. Blakely, C. D. M. Gaddis, and Doc. Hamilton, all of Kingman.

The mine is developed principally by a 300-foot shaft and two levels, each containing about 300 feet of drift, and the ore is said to be stoped out from the surface down to the first level.

The country rock is principally black amphibolite schist, mica schist, and gneissoid biotite granite. The fissure containing the deposits is 2 to 4 feet in width, all of which is said to consist of low-grade ore. It strikes in general west northwest and dips about 65° S. At the shaft the strike is east and west, but a short distance east of the shaft the vein curves to the north and is said to split. At the surface west of the shaft it is 2½ to 3 feet thick, is dark and iron-stained, is parallel streaked or banded, and, like the Windy Point vein, is very arsenical.

The ore, like that of the Windy Point, is sulphide ore. It contains argentite, ruby silver, native silver, gold, and a trace of lead, all in association with arsenopyrite and pyrite. The ore shoot ranges from a few inches to 20 inches in thickness. The ore is mostly of

high grade, but that in the deeper part of the mine is reported to be too base or refractory to be handled advantageously with methods employed a decade ago. In former times some of the ore was shipped to Swansea, Wales.

STANDARD MINE.

The Standard (formerly Blue Bird) mine is about 200 feet southwest of the Golden Star mine. It is owned by Gaddis, Perry & Co., of Kingman. It is developed principally by a 100-foot shaft and two levels containing about 200 feet of drift.

The country rock is pre-Cambrian gneissoid granite and schist. The vein strikes N. 80° E. and dips about 70° S. The ore contains silver and gold.

QUEEN BEE MINE.

The Queen Bee mine is in the northwestern part of the district, in the foothills just north of Niggerhead, at the head of a gulch that drains westward into Sacramento Valley. It is close to the cut-off trail leading from the Chloride road across the foothills to Mineral Park.

The mine was discovered in 1876 and worked by chloriders. It has been leased intermittently, mostly at a royalty of 25 per cent. Surface improvements, including a hoist, were installed in 1904, after which steady work, including sinking and drifting, was carried on for some time. Early in 1905 the mine was leased to the Queen Bee Mining Company, of Philadelphia. It is now owned by James Uncapher. The production is estimated to have been $35,000, mostly in high-grade ore. The mine is developed by a 435-foot shaft and about 900 feet of drifts.

The country rock is altered pre-Cambrian mica schist. It is intruded by the granite porphyry, a dike of which 200 feet thick is associated with the vein on the hanging-wall side. The deposit occurs in a fissure vein about 4 feet in width. It strikes about N. 40° W. and is nearly vertical or dips to the east at angles of about 80°. It seems to extend southward to Mineral Park Wash, about half a mile distant. The pay streak is reported to average about a foot in width and is located mainly on the foot-wall side of the vein. The ore contains gold and silver in pyrite, arsenopyrite, galena, and chalcopyrite. The best ore yields 200 ounces of silver and 2 ounces of gold to the ton and contains native silver, horn silver, or argentite.

ARK AND SAN ANTONIO MINES.

General statement.—The Ark and San Antonio mines (Pl. VII, *A*) are located in the southwestern part of the district, about two miles

A. ARK MINE AND MILL AND TURQUOISE MOUNTAIN, LOOKING NORTHEAST.

B. BANNER GROUP MINE AND MILL, LOOKING NORTH.

southwest of Mineral Park, in low foothills at the western base of the range and the border of Sacramento Valley, at an elevation of about 3,800 feet, in what is commonly known as Ark Basin. The mines are on adjoining claims, but on separate veins. (See fig. 12.) They are owned by the Ark and San Antonio Mining Company and have been worked for many years. Many of the owners are Mexicans residing in Mohave county. Much of the ore produced was rich and was shipped to mills and smelters.

The country rock is the pre-Cambrian gneissoid complex.

Ark mine.—The Ark mine is developed mainly by a 250-foot shaft, three levels, drifts, stopes, and winzes, aggregating about 1,500 feet of underground work. The levels are located at 50, 110, and 210 feet below the surface. They contain, respectively, 380, 400, and 500 feet of drifts. The mine is stoped from the surface to the 210-foot level. It produces considerable water. The principal surface equipments are a steam hoist and a Dodge pulverizer octagon revolving mill having a capacity of 40 tons of soft ore or 16 tons of hard ore a day.

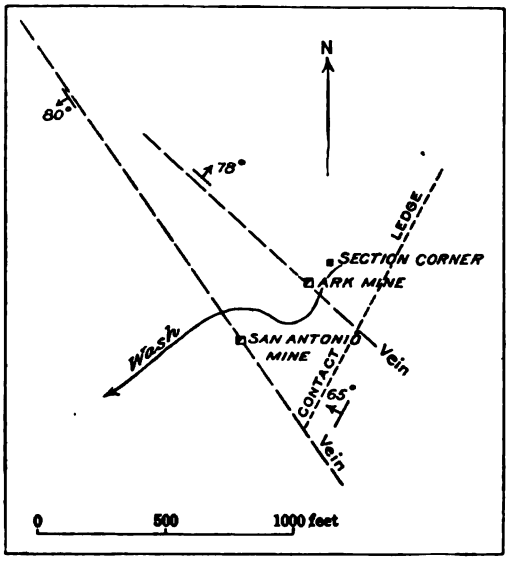


FIGURE 12.—Sketch showing relations of Ark and San Antonio veins.

The deposits occur in a fissure vein, which, as shown in figure 12, strikes about N. 50° W. and dips about 78° NE. It is 5 to 6 feet in width, is locally accompanied by 6 inches to 1 foot of gouge, in which are said to occur native copper nuggets as large as a man's hand. The foot wall is pre-Cambrian (?) medium-grained biotite-microcline granite. The gangue is quartz and somewhat silicified, crushed, and recemented granite. The sulphide ore contains pyrite and chalcopyrite with silver and gold, and the best yields about 175 ounces of silver and several ounces of gold to the ton. A 30-inch ore streak is reported to have netted $600 a ton. The production of the mine is reported to be about $150,000.

San Antonio mine.—The San Antonio mine is developed by a shaft 210 feet deep and by drifts. At the 60-foot level the drift extends 70 feet from the shaft to the northwest, and from this point up to the surface the vein was stoped out by O. F. Kuencer.

The deposits occur in a fissure vein, which is about 4 feet thick. As shown in figure 12, it strikes about N. 35° W. and dips about 80° SW. The gangue is quartz, and the ore occurs in shoots near the foot-wall side. The oxidized portion of the vein resembles crushed and recemented altered quartz and rock. It is stained brown and black by iron and manganese. The unoxidized portion consists mainly of dull-gray quartz imperfectly banded and locally with comb structure. It is porous or honeycombed and in places carries bands of pyrite an inch or more in width. The values are in silver and gold. No copper seems to be present. Of the ore mined by Mr. Kuencer 114 tons are stated to have averaged 174 ounces of silver and 3.15 ounces of gold to the ton. The production of the mine is reported to be about $75,000.

Cross vein.—About 300 feet southeast of the Ark and San Antonio mines, as shown in figure 12, is a third vein, which might well be referred to as the cross vein, for, roughly speaking, it lies nearly at right angles to the Ark and San Antonio veins. It strikes about N. 30° E. and dips about 65° NW. It extends from the San Antonio vein beyond the Ark vein and seems to be younger than the Ark vein, which does not cut it. It is a shear zone from 2 to 50 feet in width and is reported to carry low-grade gold ore with a trace of copper.

METALLIC-ACCIDENT MINE.

The Metallic-Accident mine is in the northern part of the district three-fourths of a mile north of Mineral Park. It was discovered by T. J. Christy, under whose ownership it produced handsomely. It is now owned by Henry Lovin, of Kingman. It is an old mine on which relatively only a small amount of work has been done, the developments not extending below a depth of 60 feet, where the vein is reported to become broken and to contain some copper.

The production is said to be about $54,000, all in ore containing chiefly chloride of silver with some gold; much of this ore was very rich.

FAIRFIELD MINE.

The Fairfield mine is about half a mile northeast of Mineral Park, on open, sloping hilly ground. It is reported to be developed principally by an 80-foot shaft and a tunnel nearly 1,700 feet long, known as the Hardy tunnel. The ore is reported to be principally of low grade.

WOOD CHOPPER'S RELIEF MINE.

The Wood Chopper's Relief mine, owned by J. W. Haas, of Mineral Park, is about 1½ miles southeast of Mineral Park on the south

side of the valley, in a steep northeastern slope of the mountain, at an elevation of about 4,500 to 4,700 feet. The country rock is the dark pre-Cambrian granite porphyry, extensively intruded by a light aplitic granite. The vein strikes nearly east and west and dips about 75° N. The mine is developed mainly by two tunnels, aggregating 500 feet in length and 200 feet of drift. The tunnels are situated 100 feet apart vertically; the lower one trends S. 16° E. for a distance of 350 feet to the vein. Here in the face of a 33-foot drift to the east the vein contains 2 feet of quartz with pyrite, intrusive aplitic granite on the hanging wall. The vein looks well, but is said to carry only a little gold, with a trace of copper and silver.

The upper tunnel, situated on the same vein as the lower, lies mostly in the granite porphyry and in the oxidized zone. It contains 160 feet of drift that runs toward the west. Here the vein is 4 to 6 feet wide and consists mainly of iron-stained, streaked, and banded brecciated material. It has yielded considerable good ore, some of which averaged $500 in silver chloride and $4 in gold to the ton.

KATIE MINE.

The Katie mine, owned by C. E. Sherman, of Mineral Park, is reported to have been a producer of rich silver ore since pioneer times.

OTHER PROPERTIES.

Among the other properties in the district are the Annie, Blue Martin, Kenney, Estella, Estella-Bronco, Flora, and Congress. They are all in the prospect stage; all but the last named are east or southeast of Mineral Park and are owned by J. W. Haas.

The Annie prospect is one-eighth mile northeast of Mineral Park. It is developed by a 25-foot shaft and smaller openings. The deposits consist of a "ledge," or mineralized zone, from 10 to 50 feet in width. It trends N. 70° W. and is located on the southwest contact of a rhyolite dike several hundred feet wide, erupted through the pre-Cambrian amphibolite schist and granite. The schist is traversed by numerous veinlets of fresh iron pyrites. The deposit, however is oxidized. It is reported to carry silver, gold, and copper.

The vein of the Blue Martin prospect strikes N. 60° W. and dips about 75° SW. It is about 3 feet thick and is composed mainly of crushed quartz, containing principally dark manganese-stained chalcopyrite ore with some malachite, the ore being reported to run about $30 in copper to the ton. The country rock is a medium-grained gray granite, sparingly impregnated with small crystals of chalcopyrite.

The Kenney prospect vein consists of 2½ feet of crushed or partly brecciated iron-stained quartz and rock, which contains lead values. The country rock is the dark granite.

The Estella prospect has six veins, which are mostly small, some of the larger being about 2 feet thick. They strike mostly about N. 60° to 70° W. and dip steeply southwest. They consist principally of quartz and other oxidized material and are said to have produced good silver chloride ore, and some that contained values of $25 in gold to the ton.

The Estella-Bronco vein, to judge from the croppings, is about 4 feet thick and has an extent of at least 200 feet. It dips northeast at angles of about 80°. Its ore contains iron pyrites and green silver chloride. The vein of the Flora prospect is 20 to 30 inches wide. It dips about 30° NE., and contains two 3 to 5 inch streaks of oxidized galena ore, which is reported to average about $30 in lead to the ton. The deposit is associated with the contact of the aplitic intrusive with the older granitic rocks.

The Congress prospect, also known as the "Great Bronco," is situated in Mineral Park Wash, about three-eighths of a mile west of Mineral Park, mainly on the south side of the wash. It is owned by James Uncapher. It is a mineralized shear zone, or a fault zone, with an observed width of 300 feet and a reported width elsewhere of 600 feet. It trends N. 50° W., is in alignment with Ithaca Peak and Niggerhead, and is reported to be the same "ledge" on which the Queen Bee mine is located. It is probable that the Queen Bee and Pinkham veins and the Congress ledge are all associated in this locality, but their direct connection was not traced. The deposit occurs mainly in the granite porphyry at or near its contact with the pre-Cambrian complex. It consists of more or less silicified and in part altered and iron-stained gray porphyritic granite, with pyrite and chalcopyrite forming the principal part of the ore, disseminated more or less throughout. The deposit, where best exposed and opened in the wash by shallow workings extending more or less across it, is reported to average about $5 a ton in copper, silver, and gold. Here conspicuous patches and areas of malachite and azurite resulting from recent oxidation occur on the surface and basal slopes of the workings, and much of the surface diggings is stained yellowish and greenish. The deposit has received the consideration of some of the largest companies in the Southwest. Whether values will be found in depth seems doubtful.

The McDonald prospect, situated within a few hundred feet of the top of Cherum Peak on the south side, is on a ledge that dips steeply north and is reported to contain tungsten ore.

The Argo prospect, said to be located at an elevation of about 6,000 feet, is reported to have shipped some high-grade ore running from 200 ounces up in silver and containing good lead values.

The Swift claim is said to have produced and shipped some ore containing good values in gold, silver, and lead.

The ore shoot of the Sabbath Bell vein, opened by a 90-foot shaft, is reported to contain about 2 ounces of gold and 40 to 50 ounces of silver to the ton.

CERBAT DISTRICT.

GENERAL OUTLINE.

LOCATION AND HISTORY.

The Cerbat district extends southward from the Mineral Park district for about 4½ miles and from the border of Sacramento Valley on the west to the crest of the range on the east, with a maximum width of about 3 miles in the southern part.

Cerbat, the principal camp and post-office, is situated on Cerbat Wash in the foothills at an elevation of about 4,000 feet, 3 miles from the nearest station of the Arizona and Utah Railroad on the west and 14 miles north of Kingman. Its origin dates from the early sixties, when the Golden Gem, Cerbat, Idaho, Twins, Champion, Vanderbilt, Eureka, Flores, Esmeralda, and Columbus mines were discovered or opened. It has always been a producer of high-grade ore and is reported to have produced more than $2,000,000.

A small smelter was operated here in the so-called Indian days, in the middle of the sixties, but for want of proper fluxes, for which tin cans and scrap iron were substituted, the process was not very successful, the lead being turned out in an extremely crude state.

TOPOGRAPHY.

The district ranges in elevation from 3,000 feet in the foothills on the west to 5,000 feet on the east. Stockton Hill, on the opposite slope of the range, is reached by trail only. (See fig. 16.)

The southern part of the district is drained mainly by Cerbat Wash, which leads westward across the district into Sacramento Valley. Its principal tributary from the south is Charcoal Canyon, which is several miles long and joins it just below Cerbat.

The northern part of the district is drained principally by Long Wash, which leads northward and westward into Sacramento Valley. The nearest railroad station to this part of the district is Mineral, about 3 miles to the west. Several small depressions which open into Long Wash from the east are known as Union Basin, Todd Basin, and Lane Springs Basin.

GEOLOGY.

The country rock is the pre-Cambrian granite, gneiss, and schist complex. It is intruded by dikes of minette, granite porphyry, diabase, rhyolite, basalt, and other rocks, some of which are associated with workable veins and are too greatly sericitized for determination. The complex is also flanked on the west by masses of the Tertiary volcanic rocks, principally rhyolite.

Probably the best exposure in the Cerbat Range is in Charcoal Canyon southeast of Cerbat. The canyon cuts across the beds diagonally and exposes most of the pre-Cambrian rocks, including granite, gneiss, pegmatite, schists, and syenite, together with veins and dikes occurring in the complex. The series is cut by faults, some of which now contain ore bodies.

The schistosity strikes north-northeast, with dip mainly west-northwest, varying from 70° to vertical, and the jointing trends west-northwest, with steep dip to the northeast.

Prominent among the dikes is the well-known "great white dike," so called from the fact that it weathers light buff. It extends throughout the greater part of the canyon and is associated with workable ore deposits. It is 40 feet or more thick. It crosses Cerbat Wash near the mouth of Charcoal Canyon, underlies the Gross ranch to the northwest, and is reported to extend much farther. It is a dark greenish basic rock, which is now altered and sericitized beyond adequate determination. Though profusely jointed and sheared, it seems to be younger than the granite porphyry intrusives with which it comes into contact.

THE DEPOSITS.

The ore deposits of this district contain principally gold, silver, and lead. They occur in fissure veins, which in general have a northwesterly trend and a steep northeasterly or southwesterly dip. Those situated north of Cerbat Wash are chiefly gold-bearing; those to the south contain principally silver and lead. The gangue is mainly quartz and the values usually favor the hanging wall. The principal minerals are pyrite, chalcopyrite, galena, zinc blende, stibnite, and native gold. Near the surface native silver, horn silver, argentite, and ruby silver appear, but the water level is only about 80 feet deep, and consequently primary sulphide ore comes in at relatively slight depth.

The deposits are opened by about thirty mines, a sketch of some of which follows. The most important mines, nearly all of which are now producing, are the Golden Gem, Vanderbilt, Champion, Oro Plata, Paymaster, New London, Idaho, Cerbat, St. Louis, Flores, Twins, Columbus, Alpha, Night Hawk, and Rip Van Winkle.

MINES NEAR CERBAT WASH DRAINAGE ON THE NORTH.

GOLDEN GEM MINE.

Location, history, and production.—The Golden Gem mine is located at Cerbat, on the hillside which slopes to the west. The mine was discovered and began to ship ore in 1871. Subsequently it lay idle for some time until it was acquired by T. L. Ayers, who shipped a very large amount ($200,000 reported) of rich (5-ounce) gold ore. He also hauled some of the ore to the C. O. D. mill, and left over

2,000 tons of second-grade ($24) ore on the dump, much of which still remains. Later the property was bonded to the Golden Gem Mining Company, of New York, of which Senator Warner Miller was president. This company sunk the shaft deeper and drifted, but as the ore on the 300-foot level fell off in grade, the mine was closed in 1904. It remained idle until 1906, when it was sold for $75,000, and is now owned by the Golden Star Mining and Milling Company.

A 40-ton mill with four Nissen stamps, recently installed, is now daily turning out about $350 worth of concentrates from the ore formerly left on the dump. Twenty per cent of the gold is collected on the plates. Preparations are being made to unwater and retimber

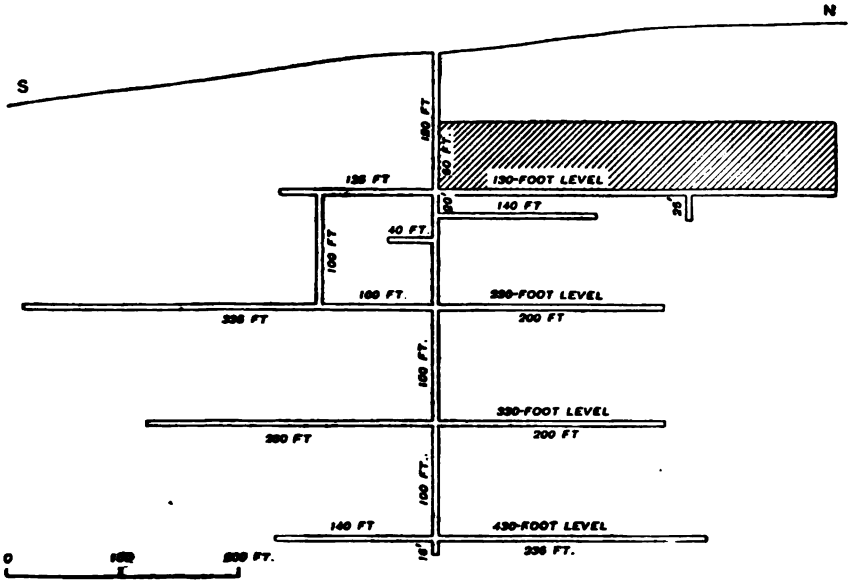


FIGURE 13.—Longitudinal section showing development of Golden Gem mine.

the old shaft of the mine, which at the time of visit was filled with water to the 200-foot level. This mine has produced good ore from the surface down, and the total production is said to have amounted to $190,000.

Development.—The mine is developed principally by a two-compartment shaft, 435 feet deep, and four levels containing about 1,200 feet of drift, winzes, and stopes. The levels are located at 130, 230, 330, and 400 feet below the surface. The first level contains 350 feet of drift north and 135 south from the shaft; the second level 200 north and 355 south, the third level 200 north and 200 south, and the fourth level 246 north and 140 south. (See fig. 13.) The only stopes are on the 130-foot level. They extend 66 feet horizontally and from 62 to 81 feet vertically.

The principal surface equipments are the 40-ton mill above mentioned, a 34-horsepower hoist, and distillate engines, aggregating 79 horsepower, for operating the plant.

Geology and ore deposits.—The country rock is the pre-Cambrian granite, gneiss, and schist complex. Fine-grained iron-gray gneissoid schist usually forms the hanging wall of the vein. The structure trends north-northeast and the rocks are intruded near by by diabase and granite porphyry or monzonite porphyry dikes. The much-altered diabase occurs in association with the vein.

The vein strikes about N. 40° W. and dips about 78° NE. It ranges from 6 to 14 feet in width and usually carries from 2 to 6½ feet of pay ore running from $10 to the ton upward. The ore shoots are reported to be more regular in the deeper part of the mine than near the surface.

The gangue is chiefly quartz and altered rock and is imperfectly banded. Some of the quartz is similar to the Gold Road type described on page 158. The ore contains chiefly gold, but carries also silver in places as high as 60 ounces a ton. The ore minerals are galena (5 or 6 per cent), zinc blende, pyrite, and stibnite. The vein is banded and shows evidence of intradepositional faulting. The values usually favor the foot wall, but vary in position, and locally rich ore streaks 2 feet wide occur on both sides of the vein.

Southeast of the mine the vein is about 6 feet in width and, as shown by croppings, extends about one-fifth of a mile to Cerbat Wash, where there are some indications that it may be split. So far as opened in the mine and two surface prospects beyond, the ore is reported to run about $20 to the ton.

On the 130-foot level, 270 feet northwest of the shaft, the vein is faulted off diagonally along the schistosity on the south or foot-wall side of a 4-foot band of dark schist. The ore shoot from the shaft to this point looks well and is reported to average high in gold.

The face of the drift extending south of the shaft on this level is reported by the foreman who had charge when the mine was suspended to contain a 24-inch streak of $48 ore.

VANDERBILT GROUP.

General description.—The Vanderbilt group comprises the Vanderbilt, Idaho, and Columbus mines, situated near together in the foothills at Cerbat, just north of the Golden Gem mine. The group is owned by the Cerbat Mining Company, with headquarters at St. Louis. At the time of visit the company was installing a 25-ton mill to treat the low-grade ore from the upper part of the mines by calcination and amalgamation of the concentrates, there being a large

amount of low-grade ore, especially in the Vanderbilt. The ore from the lower levels, owing to its richness, is shipped direct to the smelter.

Vanderbilt mine.—The principal mine of the group is the Vanderbilt mine, located about half a mile northwest of the Golden Gem and a little above it, near the head of Flores Gulch, which drains westward into Sacramento Valley. The Vanderbilt is one of the oldest mines in the camp. It was located early in the sixties and is now producing. It is developed principally by a 300-foot shaft and 800 feet of drift and crosscuts.

The country rock (locally called syenite) is pre-Cambrian fine-grained gneissoid chloritic schist, and is probably derived from a diorite which has been greatly sericitized and otherwise altered. Associated with the vein on the foot-wall side is a "porphyry dike," which may represent the intrusive granite porphyry.

The deposits occur in a fissure vein, which, like the Golden Gem vein, dips about 80° NE. and is supposed to represent the northwestward continuation of the Golden Gem and Idaho veins beyond their point of junction.

The ore, as in the Golden Gem mine, contains chiefly gold values, but carries silver also. The ore minerals are pyrite, zinc blende, and stibnite. The ore occurs mainly on the hanging-wall side. The best grade is reported to average about $500 or more to the ton. Galena occurs from the surface down to the 200-foot level, below which no lead ore has yet been found.

From the upper levels the mine is reported to have produced $150,000, and it has also yielded considerable ore to the present company.

Idaho mine.—The Idaho mine is located at Cerbat, near the Golden Gem mine, on slightly lower ground in a gulch on the west. It is one of the early discoveries of the camp, its ore being worked by Mexicans in arrastres during pioneer days, and it has been worked in a small way since 1871. It is developed principally by a 110-foot shaft sunk on the vein and 275 feet of drift. The shaft is reported to be wholly in ore and to show in the bottom a width of 5 feet of solid ore, which averages about $20 to the ton.

The geology and the ore are similar to those of the Golden Gem mine. The vein strikes N. 20° E. and dips 80° E. It averages about 4 feet in width and its ore shoot about 2 feet. The ore contains principally gold, with some sulphide of silver, galena, pyrite, and a little chalcopyrite. The production is reported to be $250,000.

Columbus mine.—The Columbus mine is about one-fourth mile northwest of the Vanderbilt mine, near the upper side of Flores Wash. The deposits are contained in a fissure vein, which has been opened principally by two shafts reported to be 175 and 200 feet deep and by 500 feet of drift. The production is said to be several hundred tons of rich ore.

ROBERT EMMET MINE.

The Robert Emmet mine, situated north of the Vanderbilt mine, is reported to be on a large vein, which is said to contain good values in gold and to have been a producer of rich gold ore.

FLORES MINE.

The Flores mine is located in the foothills on the upper part of Flores Wash, a short distance below the Vanderbilt and Columbus mines, northwest of Cerbat, and about 700 feet above Sacramento Valley. The property comprises a group of four mining claims.

The mine was first located in 1871 by a party of prospectors from Nevada, but owing to the hostility of the Indians actual mining did not begin until 1875 or 1876. At one time the mine was known as the Five Forks mine, from the ramification of the north end of the vein into five parts.

One of the early operators was Charles M. Gross, sr., a resident of Mineral Park, who afterwards became owner of the mine. In 1888 it was acquired by the Flores Mining Company, of Philadelphia. This company at once installed a 14-ton double-rocker mill, hoist, and other machinery and worked the mine until 1893, when, owing to financial difficulties, the mine was closed and sold for taxes. It was bought by W. N. Gurley, whose widow still owns it. The mine has not been operated since 1893, and is now filled with water to the 100-foot level.

The mine is reported to be developed to a depth of about 300 feet, with but little stoping. The principal surface equipments are a 5-stamp mill and a steam hoist. The mill is equipped for fine crushing and amalgamating, as the ore contains free gold.

The production is reported to have been considerably more than $200,000.

The country rock is the pre-Cambrian granitoid schist, and the intrusive granite porphyry seems to be present near by. The deposit is in a fissure vein about 4 feet thick, which dips 80° to 85° NE., but at the surface, where the vein is crosscut by Flores Gulch, it locally dips in an opposite direction. The croppings are chiefly reddish and brown iron-stained quartz and crushed or brecciated rock.

Though some ore averaging as high as $1,000 to the ton has been produced, the ore is mostly of too low grade to ship. It is contained in an oxidized gangue, composed chiefly of quartz and altered rock.

The ore contains gold, with silver sulphide, some zinc blende, and galena. It favors the hanging-wall side of the vein. Mr. Gross is reported to have handled ore averaging $60 or more only, but the Flores Company, with the mill now on the ground, profitably handled ranging as low as $6 a ton.

ESMERALDA MINE.

The Esmeralda mine is located in low, gently rolling foothills about a mile west-northwest of Cerbat, at an elevation of about 3,750 feet. It is owned by the Ark and San Antonio Mining and Milling Company, of St. Louis. It is developed principally by a 200-foot shaft and two levels containing about 250 feet of drift, with some stoping near the surface. The 110-foot level extends 90 feet south and 30 feet north of the shaft. At the time of visit the shaft contained water. The principal equipment is a 10-horsepower steam hoist.

The production is reported to be $90,000.

The country rock is the pre-Cambrian complex, with schistose structure trending about N. 35° W. The rock is intruded near the mine on the northeast by a fine-grained granite porphyry dike, several hundred feet in width.

The deposit is a fissure vein, which strikes N. 35° W., parallel with the schistosity in the country rock, and dips about 75° SW. The vein is from 4 to 5 feet in width. Its gangue consists mainly of quartz and crushed and more or less altered country rock. Oxidation extends to the depth of 90 feet below the surface, below which the ore consists of sulphides and contains chiefly pyrite and chalcopyrite, with gold and silver. A carload of the concentrates that was shipped is reported to have averaged 13.42 ounces of gold and 40 ounces of silver to the ton. The ore usually shows a crude banding about parallel with the vein.

CERBAT MINE.

The Cerbat mine is about a mile northeast of Cerbat, and the Golden Gem mine, in the foothills, on a side gulch of Cerbat Wash and near the top of the ridge separating it from Long Gulch on the north, at an elevation of about 4,600 feet. This mine is one of the early discoveries. Two operators were killed in it by the Indians in pioneer days. It was opened in 1869 and was worked by a whim in 1875. About 1880 a large mill was installed in the gulch below the mine, but operations have now been suspended for some time. The mine is owned by the Cerbat Mining and Milling Company, of Minneapolis. It is credited with a production of about $300,000.

The mine is developed principally by a 180-foot shaft, drifts, and stopes. The principal surface equipment is the large mill above mentioned.

The deposit forms a fissure vein 4 to 10 feet wide, contained in the pre-Cambrian complex. The vein strikes north-northwest, with bold croppings locally rising 8 or 10 feet above the surface. The gangue is mostly quartz, with some crushed and recemented rock. The ore

contains chiefly gold, with silver and copper also. The copper occurs mainly in the form of chalcopyrite and carbonates. A conspicuous coating of malachite is now forming on the ore walls and surface of the workings in the mine. Most of the rich ore seems to have been taken out, but the mine is reported to contain a large amount of good milling ore.

BUNKER HILL MINE.

The Bunker Hill mine is located in the mountains, a short distance east of the Cerbat mine. It is owned by John Mulligan. It is said to contain two veins situated close together. The ore, some of which has been shipped to the Needles smelter, is said to contain high values in gold and copper.

MINES IN UNION BASIN.

Union Basin, comprising an area about 1 mile in diameter, is located northeast of the Cerbat mine, in the upper part of Long Wash, which heads to the north of the upper part of Cerbat Wash. The nearest railroad station is Mineral, 5 miles distant, reached by wagon road descending Long Wash. The basin contains about a dozen small mines and prospects, not all of which were visited. The most important are described in the following paragraphs.

PAYMASTER MINE.

The Paymaster mine is located in the southern part of Union Basin, at the head of Long Wash, about half a mile north of the Cerbat mine, at an elevation of about 4,500 feet. It is an old mine and was profitably worked in the seventies, when the cost of mining supplies and of the reduction of ore was many times what it is now. It is owned by the Victor-Paymaster Mining Company, of Los Angeles, and is now producing. The total production is reported to be about $200,000.

The mine is developed principally by a 230-foot 60° inclined shaft and about 1,200 feet of drift, with upraises and stopes. It produces considerable water. The principal surface equipments are a steam hoist and a pump. At the time of visit a gasoline hoist and new machinery were being installed for more expeditious work.

The vein is contained in the pre-Cambrian complex, strikes N. 70° W., and dips 75° NNE. Locally it attains a width of about 15 feet. The gangue is chiefly mineralized quartz, in which the ore occurs principally in shoots, ranging from 16 to 24 inches in width.

The quartz contains principally silver values, with some gold. Much of the silver is in the form of ruby silver. The ore is said to range from $50 a ton upward. Some of it contains about 500 ounces of silver to the ton.

ALEXANDER GROUP.

The Alexander group of mines is located just northeast of the Paymaster mine, on northwestward slopes between 4,400 and 5,000 feet in elevation. It comprises four claims, the Alexander Nos. 1 and 2, Lazy Man, and Granfield. The two former are situated on the same vein and the two latter on separate veins. The veins were discovered in 1880 by Captain Lane, of Lane Springs Basin, and located in 1890 by James Dundon, of Cerbat, who is the present owner. The production of the property is reputed to exceed $5,000, the main part being derived from Alexander No. 1 claim.

The Alexander No. 1 is developed by three shafts and drifts. The shafts are 60, 80, and 230 feet deep. The shaft of the Alexander No. 2 is 100 feet deep. The Lazy Man contains a tunnel 125 feet in length, and two small shafts. On the Granfield claim the vein is opened by two inclined shafts, 35 and 100 feet deep and 500 feet apart.

The country rock is the pre-Cambrian gneiss complex. The veins strike northwesterly and dip northeasterly at angles of 60° to 80°. They range from 2 to 4 feet in thickness and are oxidized down to water level, which lies at about 80 feet below the surface.

The gangue is mainly kaolin, with some quartz. It is hard in the oxidized zone, but soft below water level. The ore usually favors the hanging wall and is said to occur in a nearly continuous shoot, about 18 inches in width. It contains silver, gold, iron, and lead. In the oxidized zone it contains principally soft horn silver and gold, with a little oxide of iron and carbonate of lead, the silver in places averaging about 500 ounces to the ton. Below water level the ore is chiefly sulphide, the lead occurring in the form of galena and the iron as pyrite, and there is reported to be an increase in the amount of silver, with little or no decrease in the amount of gold.

OTHER MINES.

The Climax mine is located on rough ground in the eastern part or head of Union Basin. It formerly belonged to James Dundon, of Cerbat, who recently sold it to a stock company of Denver. It is developed by several shallow shafts and drifts. The vein dips steeply southwest or is nearly vertical. The sulphide ore contains gold, silver, pyrite, chalcopyrite, and galena. The values are chiefly in gold and silver.

The Silver, Eddy, and Tub mines are said to be located on the same vein or lode, which in the Silver mine attains a width of about 100 feet. The Silver mine, owned by James Mulligan, is said to be developed mainly by shallow shafts and several hundred feet of drift. The ore is of low grade, containing principally gold and silver values, and is said to concentrate well.

According to reports the Tub mine is developed principally by shafts and crosscuts. Here the vein varies from 30 to 80 feet in width and widens downward. It is reported to show at a depth of 40 feet a 4-foot streak of galena, containing values in gold and silver, and at 60 feet below the surface an ore body about 20 feet in width, which averages about $10 in gold and 20 ounces in silver to the ton, and contains zinc, copper, and lead. The mine is known to have produced several hundred tons of lead carbonate ore, most of which averaged about 40 per cent of lead.

The Big Bethel mine is reported to be situated on a large vein containing a shoot of high-grade ore and is credited with a production of $10,000.

The Golconda mine, owned by E. F. Thompson and E. B. Smith, is opened by shaft, tunnel, and adit drift. It is reported to have produced from essentially surface workings several hundred tons of rich ore containing chiefly gold, silver, and lead values, with some copper and zinc. Some of the ore was treated at the old Empire mill in Todd Basin with good results. Recently the 300-foot level is reported to have been driven 200 feet on a 4-foot ore shoot that assays 50 per cent of zinc.

The Green Linnet mine is said to be opened principally by a 100-foot shaft and about 500 feet of drift and to have a good showing of ore.

Some of the mines of Union Basin are now said to be shipping ore to Iola, Kans., and Oklahoma for treatment. The ore is reported to average about 50 per cent of zinc, and to contain good values in gold and silver.

MINES IN TODD BASIN.

Todd Basin, a valley about 2 miles long, is situated immediately north of Union Basin and, like it, drains westward into Long Wash. The topography is generally rugged. The mines described in the following notes are the most important in this locality.

ORO PLATA MINE.

The Oro Plata mine, one of the heaviest and most continuous producers, is located in the eastern part of the district near the axis of the range and the head of the main gulch, at an elevation of about 4,300 feet. It is reached by wagon road. The mine was first located and owned by Mexicans, under whom it began to be worked early in the seventies. It was next owned by J. P. Lane, whom the tailings are said to have netted $70,000, but who, in 1882, sold it to a party of ranchers under the lead of H. Wilson. These men worked it and shipped ore to the smelters in Colorado, and finally sold the mine to J. W. Garret in 1895. In 1897 and 1898 the mine produced $150,000. Recently it has been purchased by the Oro Plata Mining Company, of St. Louis.

The mine is developed to a depth of 980 feet, principally by shafts, drifts, adit drifts, tunnels, and stopes, aggregating, it is said, about 7,000 feet of underground work distributed on three levels. The mine produces considerable water, ample for all milling purposes. The principal surface equipments are a 20-horsepower steam hoist and an air compressor. At the time of visit ground was being broken for a new mill.

The country rock is the pre-Cambrian gneiss, extensively intruded by coarse granite porphyry, a large dike of which crosses the gulch just below the mine. In the mine the granite porphyry seems to be associated with the vein, as does also a large 40-foot dike of finer-grained granite porphyry.

The vein, about 4 feet in width, normally dips about 80° NE. It is locally enriched by intersection with another vein. (See fig. 14.)

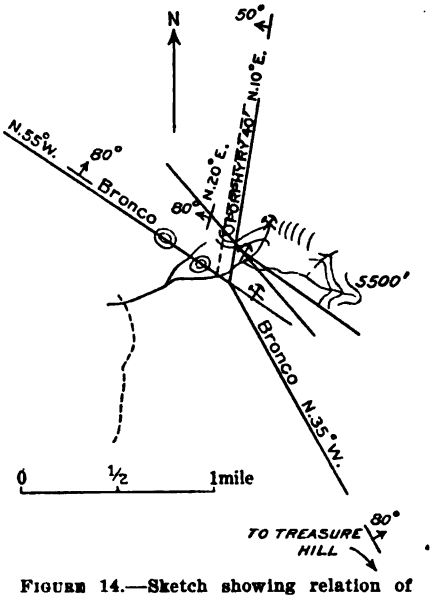


FIGURE 14.—Sketch showing relation of veins at Oro Plata mine.

The ore, which occurs chiefly in a banded quartz gangue, contains principally gold and silver. There are small amounts of chalcopyrite, zinc blende, pyrite, and galena. The ore shoots are said to be richer and more regular in the deeper part of the mine than near the surface. The ore averages in gold 3 ounces and in silver 25 ounces to the ton, and in lead about 6 per cent. There is said to be good ore in the bottom of the mine, which carries about 7 per cent of lead. The value of the output of the mine from July 14, 1896, to February 18, 1901, as shown by the sheets of the Arizona Sampler Company, which bought the ore at Kingman, was approximately $206,000 (2,527 tons of ore, averaging $80 to the ton), of which about 75 per cent was in gold and the balance in silver and lead. The price paid in the recent purchase of the mine was based on the assumption that the ore on the whole averages $37 to the ton, including the large bodies of moderate-grade ore left in the mine above the 280-foot level during earlier work.

The total production is reported to be about $500,000, and about 5,000 tons of second-class ore, said to average about $20 a ton, lie on the dump.

PROSPERITY MINE.

The Prosperity mine adjoins the Oro Plata mine, being located on the same vein where it ascends the mountain slope on the southeast. It was formerly owned by Cal. Wright and J. P. Lane, but is now owned by Owen McNally. It is said to be developed by about 700 feet of drift, mostly adit. The ore contains principally silver. Near the surface an ore body 9 feet in width is reported to have been a large producer and to have yielded considerable ore, which averaged $220 to the ton.

PRIMROSE MINE.

The Primrose mine almost adjoins the Prosperity mine on the southeast. It is owned by G. M. Bowers and T. E. Pollock. It is developed mainly by an adit drift, the breast of which is said to be in good ore, containing gold, silver, and copper. The mine produces much water and will require the installation of machinery for deep sinking.

BLACKFOOT MINE.

The Blackfoot mine, said to have been a good producer, is southeast of the Primrose mine, near the head of the gulch. It is owned by Byron Collins and Owen McNally. It is said to be developed principally by tunnels and shafts to the depth of several hundred feet. A proposed lower tunnel would cut the ore bodies at about 100 feet below the present workings. The vein is said to pinch in places, but in general increases in width with depth, and the ore shoot varies from 6 to 24 inches in width. The ore is reported to contain gold, silver, and copper, some of it running 180 ounces of silver and 3 ounces of gold to the ton and about 15 per cent of copper.

SUCCESS MINE.

The Success mine, located near the Oro Plata, is said to be opened by tunnels, drifts, and shafts on the vein. The ore is said to be sulphide and contains gold, silver, and lead. A lot treated years ago in the old mill in Todd Basin is said to have netted $27 a ton.

MEXICAN MINE.

The Mexican mine, located in the eastern part of the basin, is reported to have produced considerable ore that averaged about 9 ounces of gold and 312 ounces of silver to the ton.

MINES IN LANE SPRINGS BASIN.

Lane Springs Basin is a short, deeply cut side valley situated northeast of Todd Basin, from which it is separated by a prominent spur-

like ridge extending northwestward from the axis of the range. The basin contains six or eight mines, of which those described below are the most important.

ALPHA MINE.

The Alpha mine is located in the eastern part of the basin, at an elevation of about 5,000 feet. It is owned by Peter Cooper, Oscar F. Dennis, and Mrs. Smith. It is developed principally by two drifts, the upper one 400 feet and the lower one 200 feet in length, both of which trend about S. 30° E. along the vein, almost directly across the strike of the pre-Cambrian gneiss complex. The croppings are a prominent reef of black, iron and manganese stained quartz. The vein varies from 4 to nearly 20 feet in width, and consists principally of a gangue of imperfectly banded, fine-grained, sulphide-bearing quartz, in which the ore occurs. The ore contains silver sulphide, pyrite, galena, zinc blende, and chalcopyrite.

The mine is reported to have been a good producer. A consignment of 400 tons of ore is reported to have netted $125 a ton.

NIGHT HAWK AND RIP VAN WINKLE MINES.

The Night Hawk and Rip Van Winkle, two adjoining mines, are situated about half a mile southeast of the Alpha mine, both on the same vein in the steep northwest slope of the mountain, at an elevation of about 5,000 feet. The country rock is pre-Cambrian gneiss. The vein strikes northwesterly. In the Night Hawk it is reported to be developed principally by a drift 1,400 feet in length, whose face is located about 700 feet beneath the apex of the vein. The vein is said to be large and to contain a "pay streak" of sulphide ore ranging from 6 to 18 inches in width. The ore shoot in two localities has feathered out, and in both has been recovered with its usual values by cross-cutting into the foot wall. Much of the ore is rich; some of it is reported to have averaged $2,000 a ton in carload lots. According to record sheets of the Sampler Company, who bought most of the output from April, 1887, to January 20, 1900, the ore averages about 3 ounces of gold and 300 ounces of silver to the ton; the production during this period was 464 tons, containing values of about $244 a ton, amounting to about $113,000. The total output of the mine is reported to be $150,000, and was produced at intervals during the last seventeen years.

MINES SOUTH OF CERBAT WASH.

The principal mines situated south of Cerbat Wash are the Champion, New London, St. Louis, and Twins. As stated elsewhere, they contain chiefly silver and lead.

CHAMPION MINE.

The Champion mine is 1¼ miles southwest of Cerbat, on the west front of the range, 600 feet above and about three-fourths of a mile distant from Sacramento Valley, at an elevation of about 4,100 feet, near the head of a short wash that leads westward into the valley. It is reached by wagon road from the west. This mine is one of the early discoveries. It was fromerly worked by James Dundon, but is now owned by the Arizona-Mexican Mining and Smelting Company, of Needles, Cal. It is producing at a moderate rate. The mine is developed mainly by shafts and about 600 feet of drift to a depth of 70 feet, and it produces a little water.

The country rock is the pre-Cambrian gneiss, and it is intruded near the mine by granite porphyry and by diabase and minette dikes.

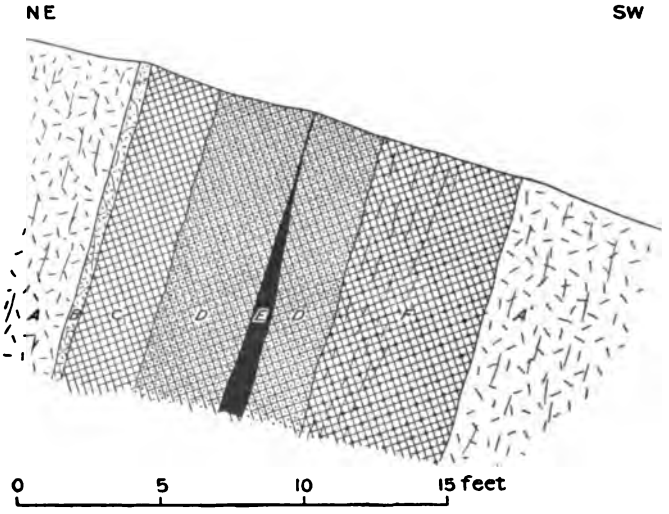


FIGURE 15.—Section of Champion vein. See text for explanation of letters.

One or more dikes are associated with the vein, which is about 12 feet in width and dips steeply to the northeast. A cross section of the vein, as sketched at the mine near the surface, is shown in figure 15. In this figure A represents country rock, consisting of alternately dark and light streaked granitic schist forming the hanging wall; B is gouge consisting principally of crushed granitic rock; C is brown, iron-stained ore; D is dark, earth-colored, fresh dike rock, which seems to be minette and contains biotite, augite, orthoclase, and andesine; E is a stringer of quartz and brown, iron-stained carbonate ore material, which widens at about 60 feet back from the face and is reported to have carried an ore shoot 1 foot in width, which, in the deeper part of the mine, becomes the main vein; F is reddish, coarse granite, or pegmatite, composed mainly of feldspar,

and toward D is sheared and cut by parallel lines produced by movement; A′ is dark granitoid schist, about the same as A, forming the foot wall. The ore is composed mainly of sulphides and contains principally lead, gold, and silver, the gold in some of it running about an ounce to the ton.

The mine has produced a large amount of ore, a considerable portion of which was high-grade surface ore. It now produces about 6 tons of ore a day, four-fifths of which is shipping ore. Only the best ore is mined. A large amount of milling ore is left in the mine and a considerable amount also lies on the dump.

NEW LONDON MINE.

The New London mine is located at the west base of the range, about one-fourth mile southwest of the Champion mine, at an elevation of about 3,800 feet, in an open wash, but little above the level of the neighboring Sacramento Valley. The mine was worked during the middle eighties, at which period it produced much good ore. It was closed about 1893 and is now dismantled of all surface equipments, but is regarded as a good property. The owners are Skee Brothers, of Santa Monica, Cal.

The mine is reported to be developed principally by two inclined shafts, drifts, and stopes. Though the deepest shaft is 150 feet in depth, the work is nearly all comprised between the 75-foot level and the surface and in a horizontal extent of 400 feet.

The vein containing the deposits is said to be similar to that of the Champion mine, but stronger, and to contain large bodies of ore. It strikes about N. 60° W. and dips 55° NE. The ore is said to average high in silver and gold, as well as in lead.

TWINS MINE.

The Twins mine is about one-fourth of a mile east of the Champion mine, in Twin Gulch, which trends northward and joins Cerbat Wash below the mouth of Charcoal Canyon. It is owned by the same company as the Champion mine, described above. It is opened by shafts and drifts to a moderate extent. It may develop into a zinc mine, for in the bottom of the mine the vein contains a shoot of zinc blende about 5 feet in width, which also contains from $7 to $8 a ton in gold. The mine is reported to have produced 300 tons of ore, aggregating a value of $10,000.

ST. LOUIS MINE.

The St. Louis mine is about half a mile east of Cerbat and the Gem mine and the same distance southeast of Cerbat Wash and several hundred feet above it. It is accessible by wagon road. The mine was discovered about 1865. It has been a producer on a

moderate scale, and is now producing under the present owner, the St. Louis Consolidated Mining and Milling Company, with headquarters at Los Angeles. This company acquired it in 1905. The property comprises 19 claims, but the developments are chiefly on the St. Louis Claim.

The mine is developed principally by adit drifts and tunnels, mostly within a vertical range of 340 feet, and contains about 1,000 feet of underground work. The shaft on the Knocker claim, however, is reported to be 110 feet deep.

Five distinct veins are reported to occur in pre-Cambrian gneiss. Several of the veins are said to converge near the southeast end of the St. Louis claim. Three of the veins trend northwest and dip 80° NE., and two trend about north and south and dip 85° E. The hanging wall of all the veins is said to be gneiss. The north-south veins are reported to have in most places a "porphyry" foot wall. These veins average about 5 feet in width and are said to be richer than the northwest-southeast veins and to contain more silver. The richest ore they contain is said to be steel galena. The ore occurs in shoots or bunches varying from 2 to 16 inches in width. It contains about $3 in gold and 12 ounces of silver to the ton and 55 to 75 per cent of lead.

The northwest-southeast veins are said to have a dark rock on the foot wall, with gneiss occurring locally on each wall. The largest of these veins is said to be 4 feet in average width, but it carries less ore than the smaller veins.

The two veins now being worked are known as Nos. 2 and 3. They are about 3 feet wide and the ore varies from 4 to 16 inches in width. In carload lots the ore is said to average about 60 per cent of lead and $2 in gold and 14 ounces in silver to the ton. Most of the ore thus far produced has been obtained within 40 feet of the surface. The management is now taking out shipping ore only and doing development work.

BLANKET VEIN PROPERTY.

The Blanket Vein property is about half a mile southwest of the Gem mine, just below the mouth of Charcoal Canyon. It is principally owned by the Golden Star Mining and Milling Company. The deposit is a gold-bearing quartz vein, resting on pre-Cambrian granite. It dips northeasterly at the low angle of about 30°, and is unique in being now bared, the granite having been completely removed from the upper surface by erosion over a nearly equidimensional area of about 500,000 square feet.

The vein is about 1 foot in average thickness and is said to contain about $8 in gold to the ton, or a total value of more than $90,000 for the area of the deposit thought to be in sight. Hornings and assays

show portions of the deposit to contain as high as $20 in gold to the ton. The gold is mostly free milling. The quartz also contains some iron, principally hematite and limonite, derived from pyrite by oxidation.

STOCKTON HILL DISTRICT.

GENERAL OUTLINE.

LOCATION AND HISTORY.

The Stockton Hill district joins the Cerbat district on the east, and is about parallel and coextensive with it north and south, being situated on the opposite slope of the mountains. It is about 4 miles in width and but little more in length. It ranges in elevation from 3,500 feet at the edge of Hualpai Valley on the east to 5,500 feet at the crest of the range.

The principal and oldest camp is Stockton Hill, situated in the foothills in the eastern part of the district, 10 miles north of Kingman, at an elevation of about 4,800 feet. It dates from early in the sixties, when the principal veins were first discovered and began to produce. In former days much of the ore was shipped to Swansea, Wales, but later it was treated in the Mineral Park and Cerbat mills and shipped to the smelters in San Francisco and to New Mexico. At present the ore is hauled by wagon to Barry or Kingman, whence it is shipped, mostly to Needles. The district is reported to have produced many million dollars' worth of ore.

TOPOGRAPHY AND GEOLOGY.

The topography, shown in part in the sketch map (fig. 16), is generally rough, but the mines are nearly all accessible by wagon roads, mostly of easy grade. The drainage issues eastward into Hualpai Valley, mainly through several short side valleys or transverse washes—the Canyon Station, C. O. D., I. X. L. (known as I. X. L. Basin from the width and open character of its middle part), Cupel, Treasure Hill, and Maywell. In their upper parts most of the washes contract into V-shaped gulches.

The country rock is the pre-Cambrian gneiss and schist complex. It is reddish brown and iron stained and is intruded by dikes of granite porphyry, diabase, and other rocks, mostly of basic character. The schistosity trends about N. 30° E. and dips usually vertically or at steep angles to the northwest. The dominant jointing or sheeting strikes northwest.

ORE DEPOSITS AND MINES.

The deposits occur in pre-Cambrian gneiss or schist, intruded in places by a later aplitic granite or by basic dikes. They are fissure

veins, which in general strike northwesterly and are vertical or dip at steep angles to the northeast. The gangue is quartz and the ores contain chiefly silver, with some gold, lead, and copper. Primary sulphide minerals are galena, zinc blende, chalcopyrite, and pyrite, but the district owes its reputation to the rich silver ores, such as native silver, cerargyrite, argentite, and ruby silver, which were found in large quantities in the upper levels. The water level is about 100 feet below the surface. Galena is often found above it, while rich silver minerals descend to a considerable distance below it. The greatest depth attained is 400 feet.

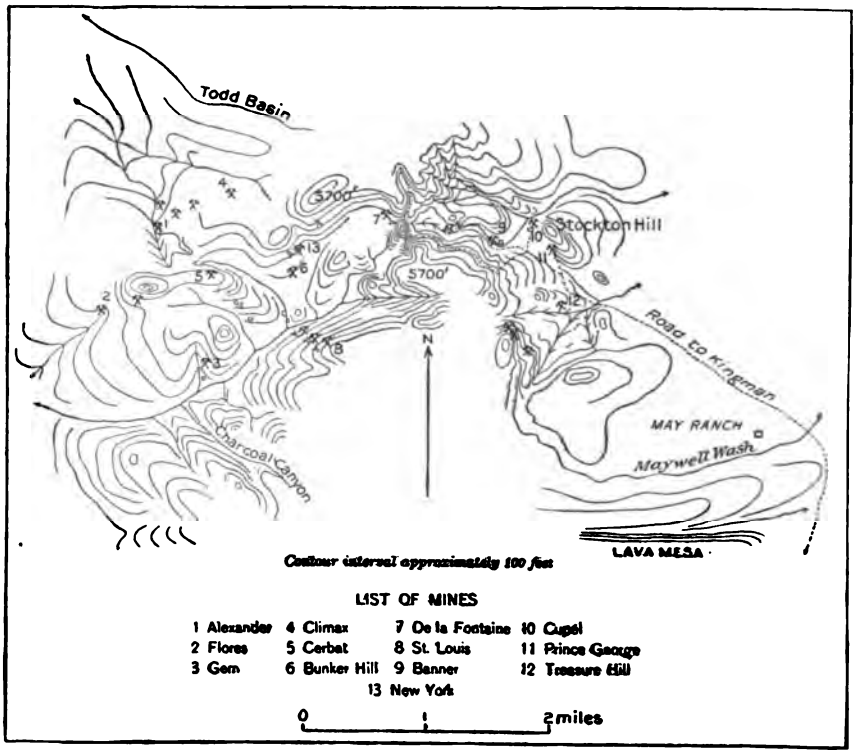
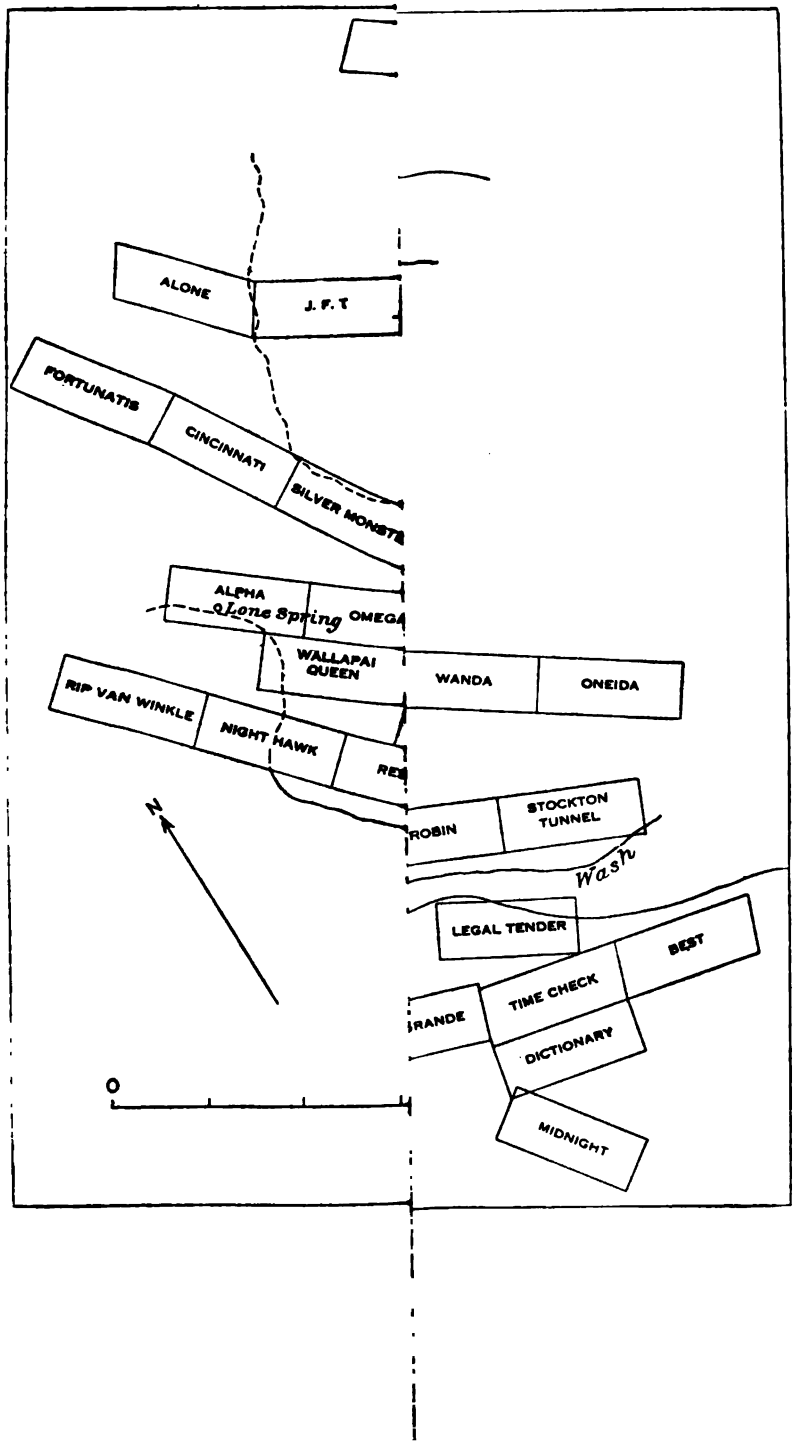


FIGURE 16.—Sketch map of Stockton Hill district and adjoining part of Cerbat district.

The district contains about 10 mines, of which the principal are the Banner Group, Treasure Hill, Little Chief, Cupel, Prince George, De La Fontaine, C. O. D., and Sixty-three. Their general distribution is shown on the accompanying sketch map (fig. 16). The principal locations made in the district are indicated on the claim map (Pl. VIII).

MINES ON STOCKTON HILL WASH.

The principal mines on or near Stockton Hill Wash are the Banner Group, Cupel, and De La Fontaine. Their situation in alignment on a nearly east-west line about 1½ miles in extent has led to the


ALONE
J. F. T
FORTUNATIS
CINCINNATI
SILVER MONST
ALPHA
Lone Spring
OMEGA
WALLAPAI
QUEEN
WANDA
ONEIDA
RIP VAN WINKLE
NIGHT HAWK
ROBIN
STOCKTON
TUNNEL
Wash
LEGAL TENDER
BEST
TIME CHECK
DICTIONARY
MIDNIGHT
N
0

current belief that they are all on the same vein. They are perhaps in a general way in the same mineral zone, but as the strike of the veins at the different mines does not coincide with the trend of the mines and the veins have not been traced and do not seem to connect from mine to mine the single-vein theory remains to be proved.

BANNER GROUP MINE.

Location.—The Banner Group mine (Pl. VII, *B*) is about half a mile west of Stockton Hill, near the center of the district, toward the upper or gulch part of Cupel Wash at a point where it widens into a small basin at about 4,800 feet elevation. The property is said to comprise six adjoining claims, of which the most important are the Infallible (formerly Indian Boy) and the Star Spangled Banner. The principal mine openings are on the former, whence the workings extend northwestward into the latter. The property is owned and operated by the Arizona-Mexican Mining and Smelting Company, of Needles, Cal., where the large smelter owned and operated by this company is located.

Developments.—The mine is developed principally by adit drifts, stopes, winzes, and shafts, aggregating about 2,500 feet of underground work, including the tunnel or adit drift, 1,600 feet in length, on the vein. This drift has a greatest depth of 230 feet below the surface. Several shafts, mostly shallow ones, are located up to 1,050 feet from the mouth of the drift. At 800 feet from the mouth of the drift is a gasoline hoist and a 60-foot winze, reported to be sunk all the way in good ore. The property is equipped with a nearly new 40-ton mill supplied with concentrating tables.

The production is reported to be many thousand dollars in gold, silver, and lead, the zinc thus far being culled and left on the dump. The dumps also contain much second-class ore, which is said to be suitable for concentration. The mine now works about 20 men and produces about 30 tram-car loads of ore a day, of which one-fourth is shipping ore and three-fourths milling ore. The ore is shipped to the Needles smelter.

Geology and ore deposits.—The country rock is light to iron-gray fine-grained gneiss, in which the structure trends about N. 30° E. and dips steeply to the north-northwest. Toward the veins on the foot-wall side the rock is red from oxidized pyrite.

The fissure vein strikes N. 40° W. and dips about 80° NE. The croppings consist principally of leached reddish-brown quartz. The vein averages about 7 or 8 feet in width; the ore varies from about 1 foot to 3 feet in width and usually occurs on the foot-wall side of the vein. In the face of the drift at the time of visit it was 2½ feet

wide, and associated with it on the hanging-wall side was a foot or more of soft gangue composed principally of crushed and altered granitic material, which, on being removed by blasting, leaves the intact ore bared in fine condition for loading on the cars. The shoot contains parallel seams of light-colored material, which emphasizes the roughly banded character of the ore.

The ore consists in places of pure galena, but usually it contains also zinc blende, pyrite, and chalcopyrite. The gold in some of it amounts to several ounces a ton. The silver occurs in part as sulphide and native, as masses and wire silver, which locally interlaces adjacent parts of the ore shoot. The amount of zinc increases in the deeper, northern portion of the mine. Toward the northwest end of the surface workings occurs a large amount of reddish quartz ore, which seems to contain chiefly gold values. This probably represents the body of rich gold ore reported to have been found in the surface openings of the mine. A short distance north of this locality galena and zinc-blende ore with comb quartz and chalcopyrite seem to prevail.

CUPEL MINE.

The Cupel mine is situated in the foothills at Stockton Hill camp, on the south side of Cupel Wash. This mine is regarded as probably the oldest on Stockton Hill. It was located about 1863, and was worked intermittently from that date to 1891, being constantly a heavy producer. It is said to have yielded handsome returns to lessees in the seventies, and in the eighties it was opened up by an inclined shaft to the 400-foot level by Spruance, Stanley & Co., of San Francisco. From this shaft nearly half a million dollars in silver and gold ore is reported to have been taken.

The principal equipments are a steam hoist and an excellent 200-ton mill and plant of the Joplin type, recently installed. The mine is owned by the Stockton Hill Mining Company, with headquarters at Topeka, Kans. The mine is developed principally by a shaft 400 feet deep, a three-compartment shaft 150 feet deep, drifts, and stopes to a depth of about 400 feet, the workings being nearly all situated within 300 feet of the main shaft. The mine is said to produce about 25,000 gallons of water a day.

The production of the mine is conservatively reported to exceed $500,000, and is variously estimated at one to one and a half million dollars. From September 3, 1885, to May 1, 1890, according to the smelter sheets, the output was $131,405, and averaged approximately 150 ounces of silver to the ton and 20 per cent of lead, silver at that time being worth about $1 an ounce. It is stated that the mine contains much ore in sight and that the dumps contain about 2,000 tons of ore that is estimated to mill $6 or $7 net per ton.

The country rock is the pre-Cambrian gneiss and schist complex. Three veins, which strike northwesterly but are not quite parallel, contain the ore. They are known as the Cupel, Edward Everett, and Tiger veins. Several diagonal or cross veins or stringers are also present. (See fig. 17.)

The ore contains ruby silver and horn silver, together with argentite, but in places is rich in high-grade galena and carries about $5 a ton in gold. The bulk of the ore produced contains ruby silver, and some of it is said to have averaged 3,000 ounces of silver to the ton and gave to Stockton Hill and the Cerbat Mountains their early reputation. Most of the rich ore thus far produced is said to have been taken out within a horizontal distance of about 250 feet, extending principally from the shaft northwestward and from the surface to the bottom of the mine. Beyond this portion of the mine to the northwest the ore is said to contain principally galena and some gold.

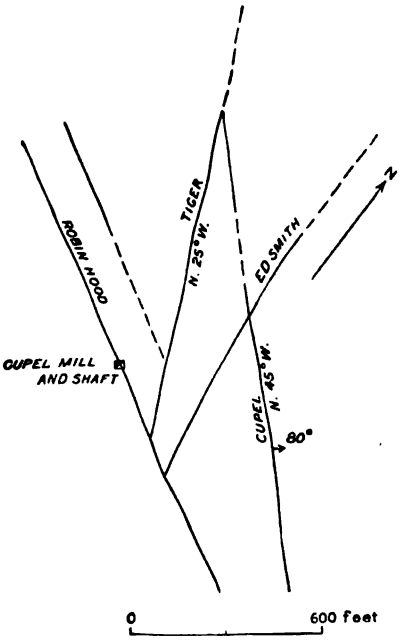


FIGURE 17.—Sketch showing relations of veins on Cupel claim.

PRINCE GEORGE MINE.

Location and history.—The Prince George Mine is located at Stockton Hill, about one-fourth mile southeast of the Cupel mine, at an elevation of about 4,600 feet. It is situated on steeply westward-sloping ground, near the head of a deep gulch that trends southward into Treasure Hill Wash.

The mine was worked principally in the eighties. After the installation of machinery the mine was operated by Mr. McKay, who soon suspended operations, since which time but little work has been done. It is now owned by the Stockton Hill Mining Company.

Production.—The production is reported to be $100,000, of which $90,000 was taken out in about ninety days, mostly from the large ore chamber.

Developments.—The principal developments are a 180-foot shaft and about 250 feet of drifts and stopes. The principal equipments are a coal or oil fuel hoist and pumps. The mine is said to produce about 20,000 gallons of water per day.

Geology.—The country rock is the pre-Cambrian complex, the prevailing phase being a medium-grained light gneiss, but next to the vein the rock is a coarse granite or pegmatite, some of which resembles graphic granite. The schistosity trends N. 30° E. and is paralleled by many small quartz stringers, none of which, however, are known to carry ore. Slickensiding in the mine indicates a nearly vertical movement.

Veins and ores.—The principal vein strikes N. 65° W. and dips about 80° NE. As shown in the mine at about 60 feet in from the mouth of the adit drift, the main vein is joined from the northwest by a second vein, which near the junction is 12 or 15 feet thick. At their junction the two veins seem to have formed an ore body 60 to 80 feet in diameter and extending to a depth of at least 50 or 60 feet below the surface. The upper portion of this ore body, particularly that in the oxidized zone, has been mined, leaving a large chamber where the ore has been removed.

The gangue is quartz and altered rock, and the ore in the unoxidized zone or lower part of the mine contains chiefly galena, argentite, and pyrite. The bulk of the ore mined from the chamber is reported to have averaged 60 per cent of lead and 300 ounces of silver to the ton, and the remainder 20 per cent of lead and 20 ounces of silver to the ton. The ore as a whole is reported to have averaged about $200 per carload, and most of the richest to have come from an ore shoot 13 feet wide.

The walls of the main vein are, as a rule, ragged, but the hanging wall of the second vein is well defined and smooth and contains a streak of ore 4 to 6 inches wide, reported to average about $600 a ton, on which the operators are now sinking. A rich 1-foot ore shoot is also reported to occur on the hanging-wall side of the main vein.

LITTLE CHIEF MINE.

The Little Chief mine is located about one-fourth mile southwest of Stockton Hill camp and about 80 feet above it, close to the main road. The mine has been worked on a small scale since the middle seventies, and has produced only high-grade shipping ore from the surface down. It is owned by the C. O. D. Mining Company. The production is reported to be more than $25,000.

The mine is developed to a depth of about 100 feet and contains about 1,000 feet of underground work, which includes a 400-foot crosscut tunnel, two 80-foot shafts, and 300 feet of drifting, the drift extending about 75 feet on either side of the two main shafts.

The country rock is the pre-Cambrian complex. To judge from talus débris on the surface at the mine, it seems to be intruded by diabase near by, and portions of a light-colored altered rock, which

seems to be the intrusive granite porphyry, are associated with the vein.

The vein trends N. 40° W. and dips steeply northeast. It is about 6 feet in width and is supposed to be the Banner vein of the Treasure Hill mine, described later. The gangue is quartz and crushed and altered silicified rock. The ore shoot locally coincides in width with the vein and is stained throughout with copper carbonate. The ore contains principally green horn silver, galena, and gold, is all of shipping grade, and is said to average about as follows: Silver, 350 ounces to the ton; gold, $5 to $10 a ton; and lead, 8 to 40 per cent.

DE LA FONTAINE MINE.

The De La Fontaine mine is situated at the west side of the district on the narrow crest of the range, at about 5,100 feet elevation, where the surface falls off steeply into Cerbat Wash on the west and Stockton Hill Wash on the east, the mouth of the adit drift or tunnel and shaft being located on the Cerbat side. The mine is owned by the Stockton Hill Mining Company. It is developed principally by a shaft 400 feet in depth and two levels comprising about 1,400 feet of drifts.

The country rock is principally a reddish fine-grained gneiss. Black amphibolite schist outcrops near by and is also present in the mine, particularly in the foot wall near the shaft on the 100-foot level. Back of the superintendent's house, a few hundred feet south of the vein, are prominent croppings of dark speckled medium-grained diorite from which the amphibolite schist has probably been derived.

The vein, which strikes N. 70° W. and dips about 80° NNE., is about 7 to 10 feet in width. The gangue is principally quartz, with some partly altered coarse granitic rock, but locally the fissure is occupied by greenish or reddish slickensiding gouge. The croppings consists of a 6-foot reef of quartz, stained by iron and manganese, and rising boldly 10 or 12 feet above the surface. The ore shoot is from 1 to about 4 feet in width. Good ore bodies of this width and of considerable extent are blocked out in the lower 300 feet of the mine.

The ore contains principally galena and zinc blende and a very little pyrite; it contains locally about $2 to the ton in gold, but the ore recently blocked out in the lower part of the mine is probably of a somewhat higher grade. The ore in sight in the mine is said to contain good values.

The company plans to treat such part of the ore as may be suitable in its mill recently installed at the Cupel mine and ship the balance to smelters.

MINES ON TREASURE HILL WASH.

The principal mines on Treasure Hill Wash are the Treasure Hill, Mocking Bird, and Sixty-three.

TREASURE HILL MINE.

Locaton and history.—The Treasure Hill mine is situated in the southeastern part of the district, in southward-sloping foothills at about 4,200 feet elevation. It was discovered late in the seventies and was worked on a small scale. From 1890 to 1900 it was owned by Lehorean Moore, who sunk five or six shafts to water level, about 65 feet below the surface, and is said to have stoped out very rich ore, some of which contained 15,000 ounces of silver to the ton. In 1902 the mine was acquired by the present owner, the Treasure Hill Mining Company, which has since sunk several shafts to the depth of about 110 feet and drifted on some of the veins, notably on veins Nos. 1 and 3. The property comprises four principal contiguous claims having a common corner and two extension claims on the southeast. The production is reported to be $100,000, of which one-half was high-grade silver ore from surface workings.

Developments.—The developments consist of a 140-foot tunnel, a 120-foot double-compartment 62° 30′ inclined shaft at the distant end of the tunnel, and a double-compartment 200-foot shaft, with drifts and crosscuts to nearly all the veins, in all aggregating about 1,000 feet of underground work. The principal equipments are a gasoline hoist, a Cornish pump with a capacity of 2,000 gallons, and engines. Heavier machinery is soon to be installed.

Geology.—The country rock is principally dark-bluish granite gneiss of pre-Cambrian age. The schistosity dips about 80° NW. The rock is intruded by a small stock of the granite porphyry. It constitutes the principal mass and upper part of the rough knob situated back of the mine and locally known as the Bronco, and it is in places associated with the veins in the mine. A schistosity is superimposed and is also older than the veins.

Veins and ores.—The veins are six in number. Beginning with No. 1, they are numbered consecutively from southwest to northeast. They average about 5 feet in width at the surface. In the southeastern part of the property they lie about parallel, strike northwest, and, except No. 4, dip for the most part steeply to the northeast. Northwest of the mine vein No. 1 curves to the left and outcrops on the southwest side of the intrusive aplitic mass, while the others lie to the east and northeast of the mass, the near ones curving out "to get past it," as the miners express it. Only the veins next to the intrusive rock are now being worked.

The gangue is principally quartz, in which the ore occurs in streaks or shoots from 100 to 200 feet long. The shoots usually favor the

hanging wall and are associated with clay gouge. The ore contains galena, with some pyrite and a little chalcopyrite. No zinc has yet been found on the property. The ore, so far as the experience of the present management goes, is said to average about 100 ounces of silver and $5 to $16 in gold to the ton, and from 7 to 10 per cent of lead, in both the oxidized and unoxidized zones.

According to reports of later (1908) work, 85 feet of drift run in the lower part of the mine, contains good milling values throughout its extent and width, and an unbroken small streak of high-grade ore.

SIXTY-THREE MINE.

The Sixty-three mine is located in the southern part of the district, about half a mile southwest of the Treasure Hill mine and several hundred feet above it, in the steep south side of a gulch which drains southward into Maywell Wash. The mine, which is one of the first discoveries, was found in 1863, from which date it is named. It at once became a heavy producer of very rich silver ore. After working the mine a few years, the first owners sold it to a San Francisco company, which worked it with good results and still owns it. Later it was also profitably worked by lessees. Subsequently the decline in the market value of silver and disagreement in the owning company are said to have led to discontinuance of work. The production is reported to be $500,000.

The mine is developed principally by adit drifts and tunnels to a depth of about 200 feet below the apex of the vein. The deposit is a nearly vertical fissure vein, about 3 feet in average width, in which the ore streaks average about 15 inches in width. The ore contains principally silver chloride and is mostly of high grade. Much of it is said to have averaged 3,000 ounces of silver to the ton. A considerable portion of the ore is said to have been treated in the Cerbat and Mineral Park mills and the rest was shipped to San Francisco. As there are no base metals in the ore, the mills are said to have extracted the values to a very high degree without roasting.

MINES IN I. X. L. BASIN.

I. X. L. Basin is an open basin-like area situated in the upper part of I. X. L. Wash, about 1½ miles north of Stockton Hill. It contains several small mines and prospects, about all of which are situated on the same vein or lode. The principal mines are the K. P. and the J. F. T.

K. P. MINE.

The K. P. mine is located in the southern part of the basin on open ground at about 4,700 feet elevation. The mine is new. It

is owned by Messrs. Kimberly and Potts, of Kingman. As the water level is at about 40 feet below the surface, the developments consist principally of shallow shafts and surface openings.

The country rock is the pre-Cambrian gneiss complex. The deposit forms a vein or lode about 65 feet in width, which dips about 75° NE., and is reported to have a horizontal extent of nearly 2 miles, many locations being made on it. The gangue or filling of the fissure consists essentially of crushed or brecciated vein quartz and crushed and altered coarse granitic quartz and feldspar. The croppings consist of similar material, locally silicified and stained reddish brown and black by iron and manganese oxides. The lode carries a width of about 7 feet of concentrating ore.

The ore is of low grade. It contains principally galena and is said to average about 60 per cent of lead. It contains also some gold, silver, and copper, the copper occurring as bornite and chalcopyrite.

J. F. T. MINE.

The J. F. T. mine, located in the upper or northwestern part of the basin, is said to be developed to a depth of about 200 feet. It is reported to have been a good producer, and its ore is said to contain copper, silver, and gold.

MINES IN C. O. D. WASH.

C. O. D. Wash is located about a mile north of I. X. L. Basin. Its principal mine is the C. O. D. mine.

C. O. D. MINE.

Location and history.—The C. O. D. mine is about 2½ miles north of Stockton Hill, in the upper or gulch part of C. O. D. Wash, at about 4,900 feet elevation. It is easily reached by a good wagon road. The mine was located about 1878 and was worked in a desultory manner until 1885, when active work was begun on the property. About 4,000 tons of ore was produced in the next seven years. Activities were renewed about 1900, with an output of several hundred tons of concentrates. In 1902 machinery and a mill were installed, immediately after which the mine and mill were operated for a period of six months, when, owing to decline in the market value of silver and, it is said, mismanagement and lack of proper machinery, the plant was closed. Later the Fletcher Mining Company leased the mine under bond and worked it for a short time, shipping the ore to Needles, but is said to have soon stopped operations for want of funds. The mine was closed again November 19, 1904, and operations have not yet been resumed.

The property is reported to comprise eight claims. It is now owned by the Taggart Mercantile and Mining Company, of Kingman. The mine is filled with water up to the first level.

Developments.—The mine is developed principally by a main shaft (No. 1) about 400 feet deep and by drifts and stopes on and between two main and two subordinate levels, aggregating about 2,500 feet of underground work.

From the second or 300-foot level to the surface the ore, except some of low grade, has been mostly stoped out for a distance of about 400 feet on either side of the shaft, especially on the east side, beyond which good ore is reported. The second level extends to a point 900 feet west of the main shaft, where connection with the surface is contemplated by a new double-compartment shaft (No. 2), which is now 96 feet in depth and on completion is to be used as a main working shaft of the mine. At about 1,200 feet west of this shaft a third shaft (No. 3) is sunk to the depth of 60 feet.

The principal surface equipments are a 50-ton concentrating mill containing rolls and three Bartlett concentrating tables, a 50-horsepower engine and boiler, and two rock crushers; a steam hoist with a 40-horsepower engine; a gasoline fan with a 10-horsepower engine, and a pump. The principal source of the power used is fuel oil. The mine is reported to yield sufficient water for operating the plant.

Geology.—The country rock is mainly dark-gray coarsely porphyritic gneissoid microcline granite. It is the dominant rock from Stockton Hill to a point beyond C. O. D. Gulch. Locally it is associated with dark fine-grained chlorite schist, in which the 60-foot shaft on the west is located. The rocks are cut by dikes of a greenstone or altered basalt. Schistosity and jointing strike N. 20° W., with vertical dip. A secondary system of joints trend N. 70° W. and dips about 80° S. and seems to be parallel with the C. O. D. vein, whose fissure probably belongs to the system.

Veins and ores.—The vein is well known as the "C. O. D." vein; it strikes N. 85° W. and dips about 80° N., and is reported to be more than a mile in length and about 6 feet in average width. The gangue is mainly quartz, in which the ore occurs in shoots and lenses which vary from 1 to 7 feet in width and are mostly of considerable extent. The narrow shoots are said to be usually rich, and the wider ones contain large bodies of milling and concentrating ore. At the 250-foot level the ore shoot is reported to vary from 3 to 7 feet in width and its ore to have averaged about $250 to the ton.

The ore contains principally silver sulphide and gold, with some galena, zinc blende, and below the 250-foot level a little chalcopy-

rite.[a] It is said to be less rich in the sulphide zone in the lower part of the mine than in the oxide zone near the surface. Its run of mine, roughly computed from a record of the output from October 10, 1885, to March 6, 1901, is about as follows: Silver 160 ounces and gold 2 ounces to the ton; lead, 12 to 20 per cent.

Production.—The production is reported to be $1,300,000, that of silver alone amounting to about $1,000,000; and several thousand dollars' worth of medium-grade ore are said to now lie on the dump. The output was mostly made between the autumns of 1885 and 1892. During this period 3,687 tons of ore are reported, according to smelter return sheets, to have contained about 402,000 ounces of silver, 1,180 ounces of gold, and 515,760 pounds of lead. Later, about 1900 to 1902, about 17,550 ounces of silver, 180 ounces of gold, and 114,360 pounds of lead are said to have been obtained from 330 tons of concentrates.

MINES OF CANYON STATION WASH.

In Canyon Station Wash, about a mile north of C. O. D. Wash, there are reported to be several small mines, of which the most important seem to be the Baden-Baden, King, and Queen mines, said to be owned by Lewis Davidson, of Kingman.

MINES IN "TOP OF STOCKTON HILL" AREA.

The "top of Stockton Hill" is situated in the northwestern part of the district, at the crest of the range, between the northern part of the Cerbat district on the west and the heads of I. X. L. and C. O. D. washes on the east. The mines include the Cincinnati, Miner's Hope, Blue Bell, Fountain Head, Brown, and others, the most important of which seems to be the Cincinnati. It is situated near the crest of the range about midway between Lane Springs and I. X. L. basins. It has not been worked for many years, but is regarded as a good property.

GOLD BASIN DISTRICT.

GENERAL FEATURES.

The Gold Basin mining district, of which Basin is the post-office, is situated in the eastern part of the White Hills (fig. 18). It extends over a hilly area about 6 miles in diameter, sloping to Hualpai Wash on the east, and ranges from 2,900 to 5,000 feet in elevation. The northeastern portion, where most of the mines are situated, is rugged, being marked by longitudinal fault scarps and scored by

[a] The mine is said to contain no copper above the 200-foot level, but in an opening about half a mile west of the mine and about 500 feet above it, on what is thought to be the same C. O. D. vein, the ore, which here occurs in a milk-white quartz gangue, contains chiefly bornite and chalcopyrite, with some zinc blende, and about $20 in gold to the ton.

several deep transverse washes, of which the principal ones are Banker, O. K., and Cyclopic, situated about 2 miles apart. The nearest railway station is Hackberry, 40 miles to the south, with which connection is made by stage line. Colorado River lies 16 miles to the north. Mineral was first discovered here early in the seventies, but remoteness from the base of supplies, together with scarcity of fuel and water, renders operations expensive and has materially retarded developments. Nevertheless, considerable progress has been made and much ore has been produced and worked in arrastres and mills.

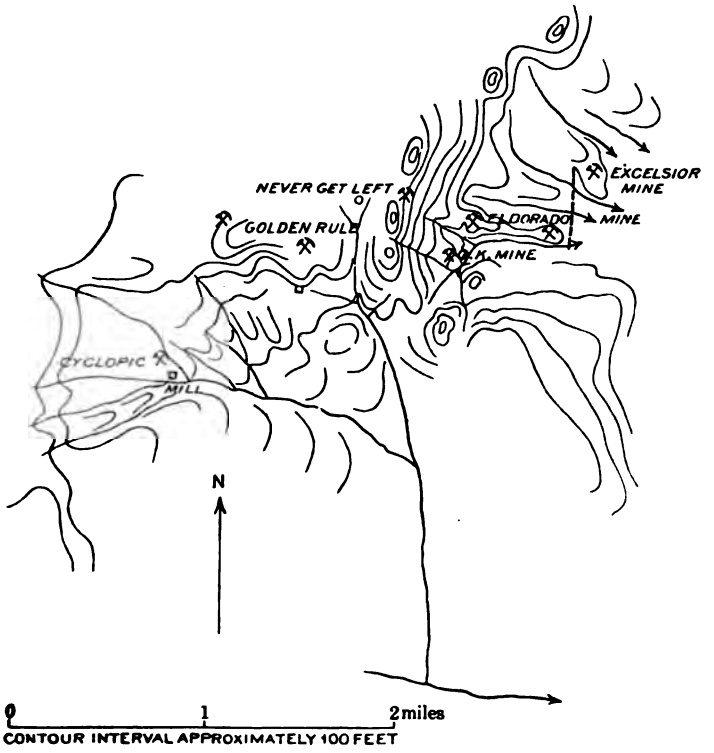


FIGURE 18.—Sketch map of Gold Basin district.

The deposits occur mainly in fissure veins in the pre-Cambrian crystalline rocks. The veins dip southeastward or northwestward, mainly at angles of 40° or 70°. The gangue is quartz, in places with siderite, and the metal is gold, mostly free milling, but it is associated with lead or copper ores, copper stain being a good indication of the gold values. Pyrite, chalcopyrite, galena, molybdenite, and wolframite are found, but the ore is largely oxidized, the water level not having been reached. Among the oxidized products are limonite, malachite, cerusite, and vanadinite.

The district contains about half a dozen small mines and about an equal number of good-looking prospects. The relative location of the most important is shown in the small sketch map (fig. 18). The principal mines are the Eldorado, Excelsior, Golden Rule, Jim Blaine, Never-get-left, O. K., and Cyclopic. The production of the district is given as more than $100,000, most of which came from the Eldorado mine.

ELDORADO MINE.

Location and history.—The Eldorado mine is located in the high foothills in the eastern part of the district, at about 4,000 feet elevation and 1,000 feet above Hualpai Wash, which is about 2 miles distant. The mine is reached by wagon road, over which most of the ore was hauled to the Basin or O. K. mill, 4 miles distant in Hualpai Valley. This mill, which was burnt while in operation in August, 1906, contained 10 stamps and a cyanide plant.

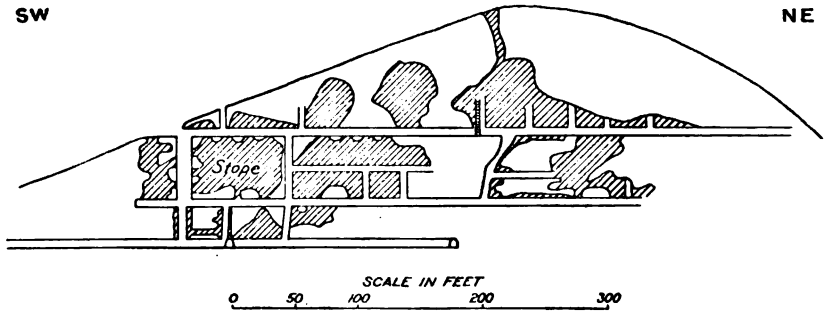


FIGURE 19.—Longitudinal section of Eldorado mine, showing stopes.

The mine was discovered late in the seventies and produced the first bullion taken from the district, much of its ore being at first worked in arrastres. It is owned by the Arizona-Minnesota Gold Mining Company, of Minneapolis. The production is reported to be $65,000, of which $5,000 was produced prior to 1902.

Developments.—The mine is developed principally by about 2,000 feet of tunnels and drifts and 40,000 cubic feet of stopes on three levels, aggregating probably about 90,000 cubic feet of underground work and distributed approximately as shown in the accompanying diagram (fig. 19). The lower tunnel trends about N. 33° E. and strikes the vein at about 200 feet in from the mouth. From this point the drift extends about 200 feet to the northeast.

Geology.—The country rock is a reddish schistose medium-grained granite. On the northeast, however, as shown at the surface and in the bottom of the mine, this rock gives way to a dark friable biotite granite. The contact between the two rocks dips about 30° W. It

is usually sharp and is probably a fault plane, which seems to cut off the vein on the northeast.

Veins and ores.—The deposit is a fissure vein, which strikes about N. 50° E. and dips 65° SE. It is continuous from the apex at the crest of the ridge to the contact in the lower tunnel of the mine and is stoped out through most of this extent. The walls are fair, but not regular. The vein averages several feet and the ore shoot about 20 inches in width. It contains iron-stained, free-milling gold-quartz ore, and is reported to average from $12 to $15 a ton in gold. The other associated minerals are malachite, lead carbonate, and vanadinite, the last occurring locally as incrustations of crystals one-fourth inch in maximum length. The principal mill treatment given to the ore was crushing, plate amalgamation, and cyanidation.

Just northwest of the apex of the vein above described and about 80 feet above it is the blanket vein, which is exposed for a length of 600 feet and a width of about 100 feet and which has contributed largely to the output of the mine. It dips about 25° E.

O. K. AND EXCELSIOR MINES.

The O. K. and Excelsior mines were discovered and located by three prospectors, Patterson, Rowe, and Fox, early in the eighties. They worked the ores in arrastres and hauled some to the 4-stamp mill at Grass Springs. In 1886 the O. K. was sold to a Kansas City company, which at once put up the O. K. mill in Hualpai Valley and ran it intermittently from 1887 to 1890. The mill burned down in 1893, but was rebuilt in 1896 and operated by lessees for a time, and then again shut down. It started once more early in 1902 and ran intermittently until 1906, when it burned down while in operation. The water used at the mills was piped from the springs or water tunnels in the upper part of Grand Wash Cliffs, 7 miles to the northeast. The mines are now owned by the Arizona-Minnesota Gold Mining Company.

O. K. mine.—The O. K. mine is about half a mile south of the Eldorado mine and about 100 feet below it, on the opposite side of O. K. Wash. The mine is developed mainly by adit drifts, winzes, and stopes on four levels. There is about 1,600 feet of underground work, distributed approximately as shown in the section (fig. 20). The production is reported to be about $25,000.

The country rock is a dark biotite granite, about the same as that which occurs in the bottom of the Eldorado mine. The strike is N. 30° E., with dip vertical. Slickensides pitch northeast-east toward the mouth of the drifts at angles of about 35°.

The vein trends N. 65° E., but curves to the north in its course and dips about 75° NW. It averages about 18 inches in width and is

composed mainly of seamed, gold-bearing limonite-stained quartz, said to average about $10 in gold to the ton. The hanging wall of the fissure is regular, but rough. Small faults 2 to 6 feet in throw occur, locally accompanied by overlap and enlargement of the vein. The ore favors the hanging wall, but where the vein overturns on the third level and the hanging wall becomes the foot wall the ore, nearly 1 foot thick, occurs in the foot-wall side.

The ore is free milling, but not so much so as the Eldorado ore, the gold being associated with cerusite. The principal other associated minerals are limonite, hematite, siderite, galena, molybdenite, and wolframite.

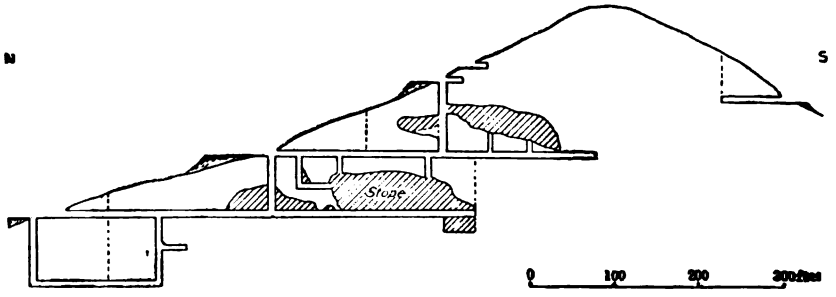


FIGURE 20.—Longitudinal section of O. K. mine, showing stopes.

Excelsior mine.—The Excelsior mine is about a mile northeast of the Eldorado and O. K. mines, in the low foothills near the edge of Hualpai Valley and about 500 feet above it, on the north side of O. K. Wash. The mine is developed to a depth of about 100 feet, principally by inclined shafts, drifts, and stopes, aggregating 500 feet of underground work. The production is reported to be $5,000.

The country rock is a coarse reddish granite associated with black amphibolite schist. The vein dips about 45° NW. It is from 1 to 4 feet in width and is locally occupied by gouge only. The ore shoot contains deeply iron-stained gold-bearing quartz or ore. It varies from three-fourths to 1 foot in width and occurs mainly on the hanging wall. The ore is said to be cyaniding ore, only a small percentage of the values yielding to amalgamation.

MASCOT MINE.

The Mascot, formerly the Old Homestake mine, is situated north of the Excelsior mine in the foothills at the edge of Hualpai Wash, and is said to contain a vein only 3 inches in width, which, however, is reported to be very rich. It is owned by the Arizona-Minnesota Gold Mining Company.

NEVER-GET-LEFT MINE.

The Never-get-left mine is located in the upper part of a cliff or fault scarp that overlooks the Eldorado mine on the east, from which it is but a few hundred yards distant. It is situated at about 4,500 feet elevation, or 1,600 feet above Hualpai Valley. It is owned by Henry Paully, of Basin, and is developed principally by an adit drift, shallow shafts, and open cuts, aggregating several hundred feet of work.

The country rock is dark gneissoid schist. The structure dips about 50° W., but the principal deposit dips about 80° N. It has a width of 6 or 8 feet and contains mainly iron-stained or copper-stained crushed gold-bearing quartz. The country rock is greatly disturbed by jointing, fracturing, and faulting, and its true character is somewhat doubtful. The mine has been a small producer for some years and was shipping ore in April, 1906.

GOLDEN RULE MINE.

Location and history.—The Golden Rule mine is about 1 mile west of the Never-get-left mine, at the extreme head of O. K. Wash, at about 4,550 feet elevation. It was discovered in the early eighties by Robert Patterson and Saul Rowe, who hauled some of the ore to the Grass Springs mill. Subsequently they leased the mine to Mr. Quackenback, and in 1900 sold it to the present owner, the Arizona-Minnesota Gold Mining Company. This company did but little development work on it till 1906. From May 15 to November 1 it was operated with a force of ten men, but was closed on the latter date. The production of the mine is estimated to be about $5,000, most of which came from the blanket vein.

Development.—The mine is developed by a 75-foot shaft, about 300 feet of drift, stopes, and a 25° incline about 100 feet long and 20 to 40 feet in width, the incline being on the south, where the deposits occur in the form of a blanket vein. The workings are contained within a horizontal distance of about 700 feet and a vertical distance of about 100 feet. The mine is handicapped by lack of water, which has to be hauled from the Cyclopic mine or from Basin, in Hualpai Valley.

Geology and ore deposits.—The country rock is the pre-Cambrian gneiss and schist. The fissure vein containing the principal part of the deposits strikes N. 20° E. and dips about 70° ESE. The croppings, which in part are prominent, form a reef of iron-stained, firmly cemented quartz breccia. The vein is best exposed in the north drift. It is about 2½ feet in average width and contains gold-bearing normal vein quartz, locally crushed, recemented, and iron-stained. Associated with it on either side is a sheet of pale grayish or whitish

gouge. The vein is said to yield good values throughout, the average being about $10 in gold to the ton, but the honeycombed quartz is the richest part of it.

At 120 feet in from the mouth of the drift the vein is abruptly cut off by a fault, immediately beyond which occurs a dark schistose rock that may be an intrusive. Near the fault the vein enlarges to about 12 feet in width, the enlargement being mainly on the foot-wall side and containing much honeycombed quartz, and the ore, greatly increased in quantity, is said to contain higher values. Some of it averaged about $100 a ton in a large chamber, from which much ore has been removed.

The fault hades north at an angle of about 10°. It is a normal one and the lost portion of the vein has risen toward the southeast. The amount of throw was not determined, but it is probably not very great. Beyond the fault the drift extends about 100 feet on the projected course of the vein which, however, has not been found.

On the south the deposits occur in a blanket vein, which is 3 to 5 feet thick, dips about 25° SE., and is probably a portion of the vein in the north drift, for it straightens up in that direction toward the top of the hill. The blanket portion has been mined over an area of about 100 feet along the strike and a breadth of 35 feet down the dip, and it probably produced good values.

CYCLOPIC MINE.

Location and history.—The Cyclopic mine is located in the southeastern part of the district, about 5 miles southwest of the Eldorado mine, near the head of Cyclopic Wash, at about 4,500 feet elevation, on open ground. It was discovered in the early eighties by Patterson, Rowe, and Glen, and about 1896 it was leased to a Seattle company. In 1901, with the Golden Rule mine, it was sold to Robbins & Walker, of Minneapolis, who milled some ore. The coarse tailings still on the ground are said to contain about $7 in gold to the ton. Since 1904 the mine has been owned by the Cyclopic Gold Mining Company, of Denver. A considerable amount of bullion is said to have been produced, but the exact amount was not ascertained.

Developments.—The mine is developed mainly by shallow, mostly inclined shafts, drifts, and crosscuts to a maximum depth of about 70 feet, but most of the workings do not extend below 30 feet. The developments probably aggregate about 1,000 feet of work.

As the mine is located in a broad wash, some of the workings have become filled with wash débris at times of flood. The principal equipments are an Ellspass mill, operated by a 26-horsepower engine, and a cyanide plant. The water supply is pumped by a small gasoline plant from the west side of the range, several miles distant.

Geology.—The country rock is a medium-grained coarsely porphyritic granite. It outcrops in association with the deposits and forms the foothills immediately on the southwest. Paralleling this rock, the wash, and the deposits on the northeast, and constituting the ridge on which the office and other buildings stand, is a fine-grained reddish granitic rock, with which is associated some of the same biotite granite that underlies the Eldorado mine. In contact with the deposits, particularly to the northwest, there is also a coarse red pegmatite.

Deposits.—The deposits are ill defined and not well understood. They consist of gold-bearing iron-stained breccias and sands of vein quartz, in a few places somewhat resembling conglomerate. This material is cemented by silica and iron oxide, but is in part loosely coherent. It trends from a point near the mill N. 57° W. up the wash and is contained in, and for the most part seems to occupy, an area three-fourths of a mile in length by about 200 feet or more in width. Prominent reefs of silicified iron-stained breccia several or more feet in width outcrop several feet above the surface. They are in practically all respects identical with the croppings of the Golden Rule and other veins that have been described. They do not, however, as a rule, continue in depth in the manner of a fissure vein, nor seem to have any definite fissure wall, but usually at a short distance below the surface give way to less firm material having an imperfect synclinal structure. In the northern part, the pseudovein croppings dip toward each other and their attitude suggests that they may be synclinal limbs of the same vein deposit.

From the principal openings near the mill in the southeastern part of the deposit the croppings representing the main or Cyclopic vein extend N. 57° W. They are continuous for the first 400 feet and are accompanied by some underlying vein quartz or ore and show ore in sight at both ends of the 400-foot excavation. Between this vicinity, however, and the northwest limits of the deposits, the croppings of the vein are interrupted, and some pits and cuts have failed to find ore there.

The croppings of the other vein extend without interruption from a point about one-fourth of a mile northwest of the principal opening for a distance of 350 feet to the northwest. They are nearly parallel with the main vein, from which they are about 350 feet distant.

The ore thus far has been derived mostly from these veins, but crosscuts 80 feet or more in length have been run in a considerable portion of the deposits between them and report fair values, which, however, seem to occur in lines or zones paralleling the deposit. Practically no mining has been done below a depth of about 30 feet. Near this level there is reported to occur a bed of red clay or gouge, which was formerly supposed to mark the lower limit of the ore, but

ore is said to have been found below it. The altered granite for a width of 100 feet or more bordering the deposit is also said to contain $2 to $4 a ton in gold.

The ore is of low grade, and is said to mill on the average from $7 to $8 a ton in gold, and to cyanide well. It contains also a little silver and a trace of copper, the latter occurring chiefly as malachite and not in sufficient amount to interfere with the cyanidation. The company is reported to have recently computed about 1,000,000 tons of ore in sight.

GOLD BELT MINE.

The Gold Belt mine is located on the southeast side of Banker Wash, at about [illegible] feet elevation. It is owned by Henry Paully. The country rock is amphibolite schist, dipping about 30° W. At the principal openings the deposits are contained in a [illegible] of quartz 15 feet thick, inclining gently eastward, [illegible] a distance of about 30 feet. The eastern opening [illegible] veins, each 2 to 6 feet in thickness, dipping [illegible] separated by a 4-foot dike of some volcanic rock [illegible] is altered beyond identification.

[illegible] of two grades, the lower grade yielding from [illegible] ton and the better grade from $16 to $20 to [illegible] as high as several hundred dollars a ton, that occurring [illegible] or honeycombed quartz being the best. The deposit [illegible] have produced a few hundred dollars' worth of ore.

SENATOR MINE.

The Senator mine is located some distance beyond the border of the [illegible] district, about 7 miles northwest of the Eldorado and [illegible] mines and about 7 miles south of Colorado River, on a [illegible] at the southeast base of a prominent landmark known as "Senator Mountain." The mine was discovered late in the eighties by [illegible] Bennett, who in 1892 sold it for $14,000 to Senator Page, of [illegible] who in turn sold it to a Colorado company. The company [illegible] installed a 10-stamp mill on Colorado River, 2 miles [illegible] Hot Springs, operated the mine and mill for about six months, [illegible] suspended. Later the property was acquired by or leased to [illegible] Hot Springs Mining Company, which operated it about a month [illegible] and shut down, the ore being of too low grade to pay for its [illegible] to the mill, 7 miles distant, and for bringing supplies from [illegible] and Kingman, 50 and 60 miles distant, respectively. The [illegible] reported to have been abandoned since then.

The mine is developed principally by open work, cuts, and adit [illegible]. The deposits are said to be nearly flat lying and similar in [illegible] to those of the Cyclopic mine (p. 125), but they form a

larger body. The ore is said to be similarly low in grade, averaging about $3 in gold to the ton. According to Comstock,[a] the deposits exhibit structural features resembling those of "brecciated fusion" and "cooling lamination" and in origin seem to be associated with igneous intrusion.

DEPOSITS AT SALT SPRINGS.

The Salt Springs mine is about 7 miles northeast of the Senator mine and several miles south of Colorado River, in the first canyon west of Hualpai Wash. It is owned by the Salt Springs Mining Company, which is said to include members of the Arizona-Minnesota Gold Mining Company. The country rock is granite. The gold ore is said to occur sporadically in quartz bodies, and its downward limit is usually indicated by copper-stained quartz.

Other properties in this district are the Smuggler-Union group, the Eureka mine, and the Lutley group.

WHITE HILLS DISTRICT.

GENERAL DESCRIPTION.

LOCATION AND HISTORY.

The White Hills district is located about 28 miles north of Chloride, in the western border of the White Hills, at about 3,000 feet elevation. It comprises an area about 2 miles in diameter and is a part of the Indian Secret mining district, so named because the knowledge of the presence of its mineral was for a long time withheld from the whites by the Indians.

The first discovery of mineral in the district by white men was made by Henry Shaffer in May, 1892, through the aid of an Indian known as Hualpai Jeff, who exhibited a piece of rich silver ore at Gold Basin and showed Shaffer its source, where the Indians procured the supply of red iron oxide with which they adorned their faces. The locality is at the site of the Hidden Treasure mine.

After making several locations, Shaffer reported the discovery at Gold Basin and was soon joined by John Burnett and John Sullivan, who also located what later proved to be some of the best mines. The trio began work and were soon shipping very rich ore, some averaging $1,000 a ton. The camp soon became the largest in the region and reached its zenith in 1894, with a population of 1,200. Within a short time the camp was owned by one company, the White Hills Mining Company, of which the chief men were R. T. Root and D. H. Moffatt, of Denver. A 10-stamp mill was built early in 1904; in

[a] Comstock, Theodore B., Geology and vein phenomena of Arizona: Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 1048–1049.

large part, it is stated, to work the dumps, which had grown huge. It was a complete success.

About 1895 the property was sold for $1,500,000, according to reports, to the White Hills Mining and Milling Company, an English concern, with headquarters at London and Colorado Springs. With only a moderate amount of ore in sight, this company installed a new, fully equipped 40-stamp mill, which was never worked to its full capacity and is still standing in good condition at the edge of the hills about one-fourth of a mile south of town; an electric-light system, and an elaborate water-supply system, including 7 miles of 7-inch wooden pipe line; a large reservoir and iron hydrants of city style, at a total cost said to exceed $150,000. As the company failed to make its final payment the property was put up at sheriff's sale and bought in by the former owners, Root and Moffatt, who are said to still own it.

DEVELOPMENTS.

The developments in the district, some of which extend nearly 1,000 feet in depth, consist principally of inclines, shafts, and drifts, aggregating probably considerably more than 10,000 feet of underground work. A plentiful supply of excellent potable water, ample for milling purposes, is usually reached at a depth of 400 to 600 feet and is now present in four of the mines.

While in operation the source of power used in the mills was coal hauled from Kingman, and the joshua trees, or yucca palms, supplied fuel for the steam hoists at the mines. The principal surface equipments of the camp now on the ground, besides the mill, hoists, trams, etc., at the mines, are a large concrete reservoir and numerous, mostly vacant, frame buildings, including offices, stores, dwellings, a church, and a schoolhouse—in all but a remnant of the former town. These are situated in the southern part of the district on White Hills Wash and mostly on Main street, which trends nearly east and west, as shown in the sketch map (fig. 21). The place now contains a store and the White Hills post-office, and regularly operates a stage and mail service with Chloride and with Eldorado Canyon, Nev., with which points it also has telephone connections.

TOPOGRAPHY AND GEOLOGY.

The surface is hilly but, except on the east, not rugged, and the district drains westward into Detrital Valley, mostly by small washes and their tributaries.

The country rock is principally light medium-grained gneissoid granite containing garnet with some associated dark amphibolite schist. The schistosity dips to the northwest but varies greatly, the

rock being folded and faulted. It is overlain on the east by the Tertiary volcanic rocks, which in turn are capped by younger basalt.

The gneissoid granite, in which all the deposits occur, contains principally orthoclase, quartz, microcline, and garnet. In many places the garnet is abundant, some of it occurring as large phenocrysts, and locally the rock is traversed by 2½-foot bands or zones, fully two-thirds of which are composed of garnets about one-fourth of an inch in average diameter.

The Tertiary volcanic rocks on the east consist principally of gray vesicular altered hornblende-augite andesite, or possibly latite, as they seem to contain much orthoclase and have a trachytic groundmass. They occur principally in an elongated ridge overlying the gneiss on the east and are about 600 feet in thickness. The upper 100 feet is principally a volcanic agglomerate. This rock is capped by dark vesicular normal olivine basalt, about 20 feet in thickness, which seems to cap also Senator Mountain, Squaw Peak, and other buttes in the vicinity.

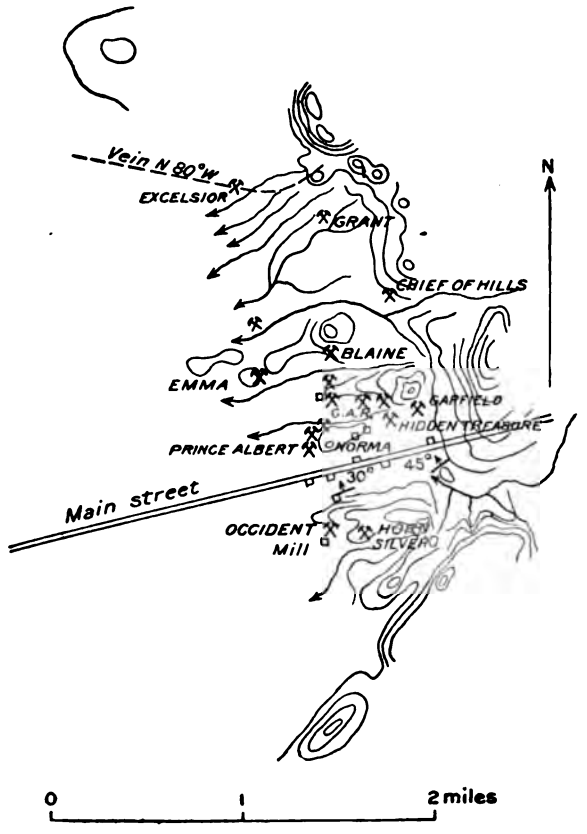


FIGURE 21.—Sketch map of White Hills district.

DEPOSITS.

The deposits are principally quartz veins, some of which are blanket veins or have a low dip. They average about 3 feet in width and in general dip to the northeast at angles of 20° to 80°. Associated with them locally are considerable manganese and iron oxide. The ore, which seems to be oxidized to the bottom of the mines,

contains chiefly chloride of silver with local values in gold, and is usually rich, being reported to average about $200 in silver to the ton. A 19-ton carload of the ore shipped to the smelter in 1894 is reported to have contained 29,000 ounces of silver and 80 ounces of gold. The miners report the best ore to occur in the "white porphyry," which seems to mean the light phase of the granitic gneiss.

The presence of yellow and brown material resembling the altered igneous rock in or associated with the veins suggests that the fissures, which the veins now fill, may formerly have been occupied by dikes of minette or vogesite that the veins have replaced. It is possible that these dikes may belong to the same period as the Tertiary volcanic rocks on the east, which at one time must have deeply buried the entire district, but it is more probable that they are very much older.

PRODUCTION.

The production of the district, which is known to be large, is reported to be about $3,000,000. Prior to the acquisition of the property by the White Hills Mining Company many lessees are reported to have made fortunes ranging from a few thousand dollars to $25,000, each from surface workings. During the first fourteen months of its ownership the White Hills Mining Company is reported to have shipped ore that netted at the Denver smelters $242,000, and throughout the period in which it operated the property large shipments of bullion are reported to have been regularly made.

MINES.

The district contains about 15 mines, of which the most important are the Prince Albert, Norma, Grand Army of the Republic, Occident, Horn Silver, Hidden Treasure, Good Luck, Excelsior, Garfield, Daisy, Bryan, Chief of the Hills, West Treasure, African, and Grand Central. They are nearly all situated within three-fourths of a mile of the camp (fig. 21) and were all discovered about the same time. A brief sketch of some of them follows. Only a few of the smaller ones in the northern part of the district are now being worked. The Occident and Horn Silver mines are situated in the hills south of town and the remainder are to the north of it.

GRAND ARMY OF THE REPUBLIC MINE.

The Grand Army of the Republic mine is located on Grand Army Wash, on open ground about three-fourths of a mile north of Main street. It is extensively developed to a depth of 700 feet, mainly by inclines, drifts, stopes, and shafts distributed on five levels, in part approximately as shown in fig. 22, the inclines being descended by tram tracks, which, together with the hoists, are still in place. Water level is reached at a depth of about 600 feet. The immense dumps indicate that much work has been done.

The country rock is gneissoid granite and schist. It is very highly altered and iron stained. The deposits are contained in two nearly parallel veins, situated about 30 feet apart, the main one being the lower. At the mine the veins strike N. 62° W. and dip about 23° NE., and the country rock seems to dip with them, but is much disturbed. At a point 150 yards southeast of the mine, however, the dip of the veins increases to about 75°, and farther on, about one-fourth of a mile from the mine, the veins appear in the West Treasure shaft, to which openings show that they are continuous from the G. A. R. mine.

In the G. A. R. mine the ore is free-milling, and much of it is very rich, some being said to average 6,000 to 7,000 ounces of silver to the ton. The mine is reported to have produced much rich ore from all its five levels. During a considerable portion of the Root-Moffatt régime the main force of the miners worked here, sometimes more than 100 men stoping at once.

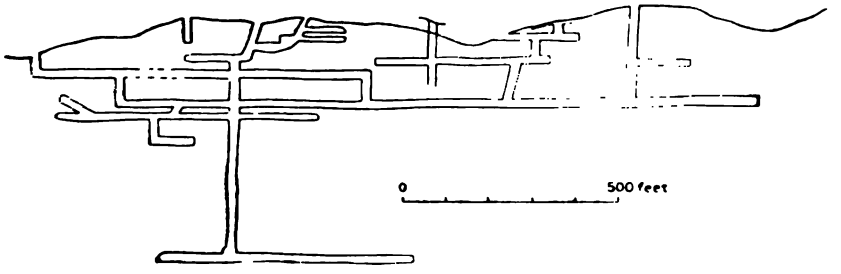


FIGURE 22.—Longitudinal section of G. A. R. mine.

WEST TREASURE MINE.

The West Treasure mine is located near the head of Grand Army Wash on the G. A. R. veins, especially on the upper vein, which is here about 20 feet distant horizontally from the lower vein and dips 65° N., while the dip of the lower vein is about 55° in the same direction. The veins seem to join each other at no great depth, and their junction has probably enriched the ore body in this mine. A large dump shows that much work has been done and the mine is reported to have been productive.

HIDDEN TREASURE MINE.

The Hidden Treasure mine is northeast of the West Treasure mine, immediately north of White Hills Wash and the upper part of town, in the east slope of the ridge, on the same G. A. R. vein. Here the vein strikes N. 80° E. and dips about 70° N. It is about 3 feet thick and is accompanied by 2 inches of reddish-brown oxidized gouge, between which and the rock wall of the fissure is an inch or two of greenish crushed rock gouge. The oxidized reddish-brown

iron-stained croppings were the source of the Indian face paint that led to the discovery of the district.

The country rock is amphibolite schist, which near the mine is greenish from the presence of epidote. It dips 20° NW.

The mine is equipped with a large steam hoist and a shaft house and has a deep shaft, but as the ore, according to report, is too base and refractory to be handled by the White Hills mill, the mine has not been extensively developed.

NORMA MINE.

The Norma mine is located in the same east-west ridge as the Hidden Treasure mine, immediately north of the town in the south side of the ridge, toward its east end. It is developed principally by shafts, drifts, and stopes to a reported depth of 600 feet. Its works, especially the tunnel, are said to extend through the ridge, coming out on the north side. In fact, a considerable portion of the ridge has been so undermined by the workings that it is said to stand on "stilts." The distribution of a part of the Norma workings is shown in the accompanying diagram (fig. 23). The dumps are large.

The country rock dips 35° N. The vein containing the deposits strikes N. 80° W. and dips about 70° N. It widens from 3 feet at the surface to 8 feet in the deeper part of the mine and contains much gouge or crushed and altered granite. The hanging wall is well defined and smooth. The production of the mine is reported to be large, but exact figures are not available.

AFRICAN MINE.

The African mine is north of the Norma mine, in the north side of the same ridge and seemingly on the same vein. It is said to be but a few hundred feet in depth and has not been extensively worked.

PRINCE ALBERT MINE.

The Prince Albert mine is immediately north of the town, in the western part of the ridge containing the Norma mine. It is developed to a depth of 300 feet or more, principally by inclines opened on the two sides and the west end of the ridge. It contains three productive, nearly flat-lying veins, which dip about 30° NNE. The two upper veins are about 75 feet apart and the lowest is 25 feet below the middle one. They lie in a dish or shallow syncline and are thought to connect with the Norma vein on the east. The veins, especially the two lower ones, descend nearly to the edge of the wash, and seem to converge on the African claim and near the Daisy mine.

The mine was a heavy producer in the hands of lessees. Its royalties of 20 per cent are reported to have amounted to $30,000 in

a short period. It seems to be mostly worked out so far as the oxidized zone is concerned, but is reported to contain much good ore still.

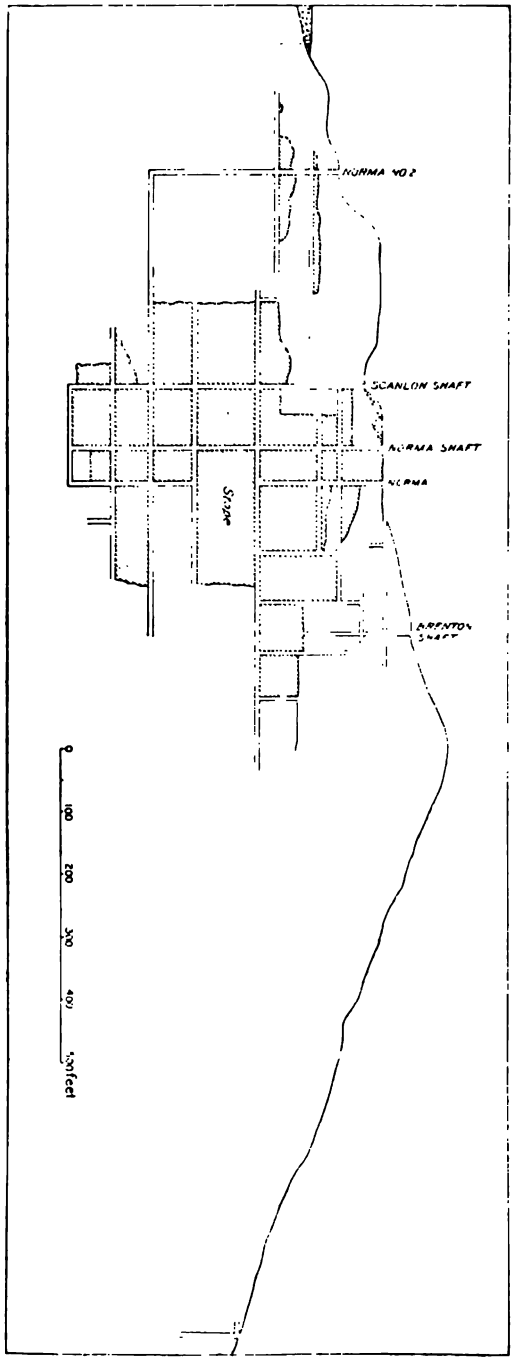


FIGURE 23.—Longitudinal section of Norma mine.

DAISY MINE.

The Daisy mine is located northeast of the Prince Albert mine, of which it is almost a continuation, in a flat of Grand Army Wash, where the converging Prince Albert veins seem to unite in a sag in the slope of the hill, with the Norma and the African situated just to the east. The vein strikes about east and west and is developed to a reported depth of 500 feet by shafts and other workings, which incline at angles of about 45° with the vein. There is a large dump of highly oxidized material. The production is said to be large and came in part from a very rich $300,000 ore shoot.

GARFIELD MINE.

The Garfield mine is located near the head of Grand Army Wash. Its workings are said to extend inward 150 feet. It was worked principally by lessees, who operated from the gulch and stoped upward. The production is reported to be about $60,000.

BRYAN MINE.

The Bryan mine is about a mile northwest of town. It is said to be developed to a depth of 240 feet. It has produced considerable rich surface ore and is reported to contain good milling ore all the way down.

CHIEF OF THE HILLS MINE.

The Chief of the Hills mine is northwest of the G. A. R. mine, near the head of the first wash north of G. A. R. Wash. It is said to be worked to a depth of about 200 feet, and has produced rich surface ore.

GOOD LUCK MINE.

The Good Luck mine, owned by A. L. McKesson, in the western part of the district, is said to have produced considerable ore. A few tons shipped in May, 1906, are reported to have averaged several hundred dollars a ton in silver and gold.

EXCELSIOR MINE.

The Excelsior, formerly the T. W. mine, is located in the northern part of the district, about 1½ miles north of the town, on open ground. It is one of a group of eight small mines or claims recently acquired by the Mohave Gold-Silver Company, with headquarters at Los Angeles. The mine is developed by a 185-foot shaft and drifts, but as the shaft had caved a new shaft 40 feet deep was being sunk at the time of visit. The dumps show considerable old work done, mostly of chloriders, who left much good ore.

The country rock is the gneissoid granite, deeply oxidized and iron stained. The vein containing the deposits is 3 to 4 feet thick, dips very steeply north or is about vertical, and seems to be about one-fourth of a mile in length. The ore usually occurs in a shoot about 7 inches in width and contains silver chloride and gold. It is all good milling ore and at the time of visit the company was planning to install a 10-stamp mill.

OCCIDENT AND HORN SILVER MINES.

The Occident and Horn Silver mines are about one-fourth of a mile south of town just east of the mill, mainly in the south side of an east-west ridge. They are situated near together on overlapping claims. They are both seemingly on the same vein, which is 2 to 4 feet in width, and contains chiefly reddish-brown iron-stained crushed and brecciated quartz or ore. It is steeper than the veins

north of town and dips about 60° N. The ore contains principally horn silver. Both mines are reported to have been heavy producers.

The country rock is the granitoid gneiss and schist complex. It dips about 30° N. At the Occident mine the rock is gneissoid granite; at the Horn Silver it is a gray schist.

The Occident mine is said to be 800 feet deep and to be extensively developed by drifts and stopes. A long drift to the west from the bottom of the shaft is said to penetrate much good ore. The mine produces a plentiful supply of good water. In the Horn Silver mine the vein flattens somewhat with depth and has been worked in part by inclines. Figure 24 is a section of the underground workings of both mines.

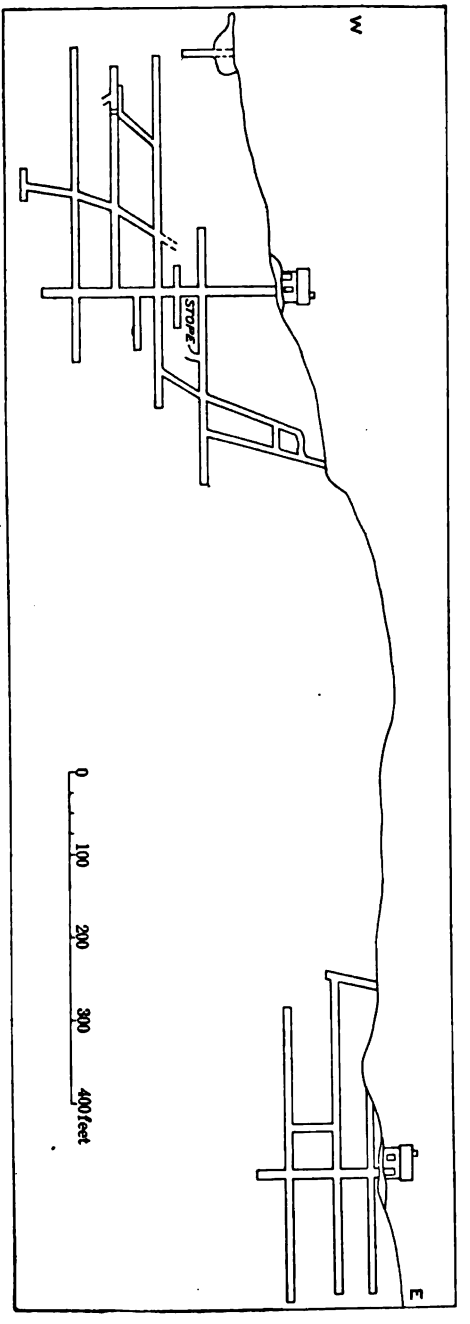


FIGURE 24.—Longitudinal section of Occident and Horn Silver mines. The Horn Silver is east of the Occident.

M'CONNICO DISTRICT.

GENERAL DESCRIPTION.

The McConnico district lies about 6 miles southwest of Kingman, southeast of McConnico station on the Santa Fe Railway, in the border of Sacramento Valley and the adjacent low foothills and scarp of Kingman Mesa, between elevations of 2,800 and 3,500 feet. It trends north and south and has a length of about 4 miles.

The country rock is principally pre-Cambrian granite, which in the valley portion of the district is covered by wash débris. The ore deposits are contained principally in gold-bearing pegmatite dikes and shear

zones, cutting the granite in a northerly direction and, in some places, are associated with later basic intrusives. The principal deposits are those of the Bi-Metal mine, the McKesson group, and the Boulder Creek group.

A good spring, Boulder Spring, occurs in the southern part of the district and water can probably be reached almost anywhere at the depth of a few hundred feet below the surface.

Specular iron occurs a short distance south of the McKesson mines. Titanite is reported in the country rock granite southwest of the Bi-Metal mine. Amethyst, associated with some stibnite and galena, is found about one-fourth of a mile northeast of Boulder Spring, in the foothills, probably as a vein pegmatite dike. This amethyst-bearing property is owned by Kinsman & Solomon. It is developed by a 65-foot shaft and has produced some good stones.

BI-METAL MINE.

Location and development.—The Bi-Metal mine, also known as the McGuire mine, from the name of its owner, who lives near by, is in the northern part of the district, about 3½ miles from Kingman, close to the railroad, in the basal west slope of Kingman Mesa. The mine is developed principally by about 250 feet of open cut, 130 feet of tunneling, and a shaft 80 feet in depth. From the mouth of the tunnel the slope of the surface is about 30°.

Geology.—The country rock containing the deposits is an altered and mineralized pre-Cambrian microcline granite. It occupies an area about 300 feet in diameter and locally seems to change into detrital masses, containing pebbles, cobbles, and bowlders of very dark to very light gray granite and schist ranging up to 2 feet or more in maximum diameter.

The structure, consisting of sheeting and cleavage, dips about 45° N., and has for the most part obliterated or obscured an older and more general north-south sheeting. Another system of jointing also dips westward about parallel with the surface slope, as shown in both the tunnel and the cut.

On the south the boundary of the mineralized area is marked by a dark-gray intrusive dike rock, which cuts the granite, contains inclusions or fragments of it, dips about 45° N. beneath the deposit, and is encountered in the bottom of the shaft. This dike rock is medium grained and consists essentially of a groundmass of plagioclase prisms containing pale-greenish hornblende phenocrysts, of which the largest are about three-fourths of an inch in length. The solutions which mineralized the deposits may have accompanied or closely followed the intrusion of this rock. On the west, toward

the railroad, the deposit is obscured by wash and débris. On the east the deposit seems to terminate above the mine at a point about where the slope steepens with overburden talus, but it may extend beneath this talus upward toward the top of the mesa and may possibly connect with a similar deposit about half a mile to the northeast.

Deposits.—The values contained in the deposits consist essentially of fine-grained free gold. As seen in the face of the tunnel and the bottom of the shaft, both the granite and the dark dike rock carry considerable iron pyrites and, according to reports, but very little gold. The same is true of the mineralized granite on the surface to the north and south of the deposit. In the oxidized and mineralized zone, however, this pyrite, particularly in the granite, has weathered out and given rise to the hematite and other forms of iron that so brilliantly stain the rock, and has left cavities or receptacles in which the gold now contained in the deposit seems to have become concentrated. Wherever this oxidized rock is crushed and panned or horned it yields a long string of fine, bright gold, and in some small gullies or lines of drainage within or at the border of the area, where further concentration by flowing water has taken place, several tablespoonfuls of mostly coarse gold, of which some of the largest nuggets contained about half a dollar each in gold value, are reported to have been panned. The gold is said to be of high grade, worth $19.50 an ounce.

The free gold to which the deposits owe their value seems to have been derived from a considerable thickness of overlying mineralized rock. As this overlying rock became disintegrated and was removed by erosion the fine gold liberated from it gradually worked into the underlying rocks in which it is now found. Below or outside of the oxidized zone of mechanical concentration probably only very low-grade ore occurs.

The mine is reported to have produced some gold, more than enough to pay for development, the gold being won principally by the use of rockers.

M'KESSON GROUP.

The McKesson group of mines is located near the middle of the district, toward its west side, on open ground in the border of Sacramento Valley, at about 2,800 feet elevation. The group comprises five or six openings situated on as many different claims within an area half a mile in diameter. The properties are all in the prospect stage and are developed principally by shallow shafts to a maximum depth of about 50 feet. They are practically all on pegmatite dikes that cut the pre-Cambrian granite. The dikes in general trend northerly, are from 2 to 10 or 12 feet in width, and contain gold in places. They also contain small bodies or stringers of quartz, some

of which is porous where its iron content has dissolved out. Whether the pegmatite, however, is primarily gold bearing or whether the gold has accumulated in its porous oxidized zone in the manner described in the Bi-Metal mine has not been satisfactorily determined. That such concentration of gold may represent the principal part of the values contained in the surface part of the deposits seems probable.

The principal deposits of the group are the McKesson "Ledge," the Santa Fe vein, and the Spot Cash prospect.

BOULDER CREEK GROUP.

The Boulder Creek group, consisting of eight claims, is situated in the foothills in the southern part of the district, at about 3,200 feet elevation. The topography is gentle and all the properties are accessible by wagon road of easy grade.

Traces of gold have been known in the region for many years and this property was discovered and located by A. L. McKesson about April, 1906, by dry washing or panning. It is now owned by the Grand Consolidated Gold and Silver Mining Company, of San Francisco. The property is developed principally by several shallow shafts and pits. Boulder Spring is located near by on the north.

The country rock is a pegmatitic granite, which is somewhat schistose and weathers into bowlders up to 60 or 80 feet in diameter. About half a mile to the southeast, 200 feet above the mine, the rock is capped by the dark lavas of Kingman Mesa.

The deposits are contained principally in two ledges, which are probably dikes, but may be merely mineralized zones in the pegmatitic granite. They lie at nearly right angles to each other and form a T-square, of which the top trends northwest-southeast and the stem extends to the southwest. The latter varies from about 100 to 1,000 feet in width, and has a known length of about one-fourth of a mile. Where opened on the northeast in the Baby Mine shaft to a depth of 30 feet it consists almost wholly of red oxidized pegmatite and is in places porous or honeycombed, where seemingly iron pyrites has been dissolved. More than half of all the material excavated from the shaft is piled up as ore and is said to contain from $3 to $100 in gold to the ton.

The northwest-southeast ledge likewise has a maximum width of about 1,000 feet and is reported to have a known extent of about a mile. It is composed of coarse granite similar to that in the Baby mine shaft. A considerable portion is stated to be ore. That from the openings on Baby Mine claim No. 2 is reported to average about $12 in gold and 20 ounces in silver to the ton, and contains also some galena and chalcopyrite.

MAYNARD DISTRICT.[a]

GENERAL DESCRIPTION.

The Maynard district is a large indefinite area in the Hualpai Mountains. The district is said to be easily reached from Kingman by a good road crossing the summit of the range via Wheeler Pass. Water can be derived from most of the mines, and pine timber suitable for mining purposes grows near by.

The first important discovery of mineral in the district was made about 1865 by a party of prospectors headed by John Moss. They located the mines known as the Pride of the Pines and the Florence, and named the district Wauba Yuma district. Soon after beginning operations they were driven from the mountains by the Hualpai Indians, then on the warpath, who continued hostile for several years following.

In 1871 Lieutenant Wheeler's party, of the War Department, in making a reconnaissance in the Territory, camped on what is now known as Wheeler Wash, on the east side of the mountains. A large party of prospectors from San Francisco soon camped near by, made locations, named the district the Maynard district after Lafayette Maynard, one of its pioneer members, and elected a recorder. The first location made was named the Wheeler lode. For a decade or more, beginning in the early seventies, the district furnished a livelihood to a considerable number of people, whose operations were confined to the rich surface ores in the oxidized zone.

The country rock is mainly pre-Cambrian red granite, said to be intruded by porphyry dikes. The zone of mineralization in which most of the deposits occur lies on the northern and eastern slopes of the mountain. In this zone the deposits are contained in strong and persistent fissure veins similar to those in the Cerbat Mountains. The width of the ore ranges from 1 inch to 3 feet. It contains principally horn silver and is usually rich, especially so where the green horn silver (bromyrite?) is present. Some of the deposits also contain copper. Among the most important of the veins are those of the American Flag, Enterprise, Great Eastern group, and Siamese group. They are mostly situated in alignment with the principal system of the Cerbat veins, agree with them in strike, and are probably contemporaneous with them in age and of the same general origin. The production of the district is reported to be fairly large.

Other metals reported to occur in the Hualpai Mountains are molybdenite, found in association with copper, and native quicksilver, associated with lead carbonate, the latter being on a claim owned

[a] Owing to lack of time this district was not visited by the writer. The account of it is compiled principally from statements found in the Mohave County Miner, verified and supplemented by verbal reports of pioneer citizens and men who have worked in the mines.

by Mr. Jackman. Just beyond, in the Aquarius Range, about 50 miles from Kingman, is a tungsten mine which annually produces 25 tons of tungsten ore, worth $400 a ton at Kingman, whence it is shipped.

AMERICAN FLAG MINE.

The American Flag mine is about 16 miles southeast of Kingman, on the eastern slope of the mountains, at about 5,000 feet elevation. It is reached from the wagon road near the summit by a 2-mile trail. The mine was discovered in 1874 by W. M. Shoulters, who is said to have sold it, after working it a short time, to John Pemberthy, William Richard, John Corin, and Joe Prisk for $25,000. These men developed it principally by adit drifts. The water level is said to lie at about 700 feet below the surface. The mine is now owned by a company of which John Pemberthy and H. H. Watkins, of Kingman, are members.

The country rock is granite. The main vein is from 1 to 4 feet in width, and the ore shoot is said to be relatively large. The ore contains principally antimonial silver, some gold, and a little zinc. Much of it is rich.

The production is reported to be about $400,000, sold from the mine, in ore that averaged more than $100 a ton. For 21 tons of the ore from the lower part of the mine shipped to Swansea, Wales, a net return of $11,500 is said to have been received.

GREAT EASTERN GROUP.

The Great Eastern mine is about 16 miles from Kingman, on the eastern slope of the mountains, about 3 miles north of the American Flag mine. It was discovered in the early seventies, and is owned by the Great Eastern Mining Company.

The deposits occur in several strong fissure veins, which strike northwesterly and are associated with a contact between the granite and "porphyry." The most important is known as the Great Eastern vein. It is opened by about 300 feet of tunnel and drifts with good results, the ore shoot being continuous for an extent of about 130 feet. The ore contains principally silver and galena, with small values in gold and copper.

ENTERPRISE MINE.

The Enterprise mine is located about east of Kingman, in the northeastern slope of the mountains a few miles north of the Great Eastern mine. The property comprises a group of six claims. It is owned by the Enterprise Mining Reduction and Improvement Company.

The mine is developed to a depth of 300 feet by a vertical shaft, drifts, and crosscuts, aggregating about 600 feet of underground work. The principal equipment is a steam hoist, capable of sinking to a depth of 1,000 feet. Water, and wood at $2 a cord, are available near by and timber suitable for mining purposes can be had about 3 miles distant.

The country rock is granite. It is intruded by "porphyry," which is also associated with the veins. The deposits are contained in several veins which strike northwestward. The principal vein dips steeply to the northeast, is from 6 to 14 feet or more in width, has well-defined walls, and, to judge from its croppings, which are prominent, and prospects, has a length of more than a mile. The ore shoots are strong and persistent. The ore contains principally galena, pyrite, and chalcopyrite, with good values in gold and silver. Small lots of about 1 ton each of sulphide ore treated at the Llewellyn test plant in Los Angeles, were concentrated 6 into 1 and gave values of $81.37, $62.29, and $57.08 a ton.

OLD HACKBERRY MINE.

In the northeastern part of the district are a number of mines of which the best known is probably the famous Old Hackberry mine. It is about 14 miles northeast of the Enterprise mine, in the eastern slope of the Peacock Mountains, an outlying range of the Hualpai Mountains, near the old town of Hackberry. It was for many years a heavy producer and is credited with a production of $1,000,000. The ores are said to have been treated by the chlorination process.

SIAMESE GROUP.

The Siamese Group mine is situated on the southern part of the east slope of the Hualpai Mountains, in the Cedar Valley district, at about 5,000 feet elevation. It is best reached from Yucca, from which it is 23 miles distant in a southeasterly direction. A wagon road extends to a point within 5 miles of the mine, with which connection is made by trail.

The property comprises nine claims. It is reported to make a very good surface showing and to be promising in copper. Since 1907 it has been owned by the Arizona-Southwestern Copper Company, with headquarters at Kingman.

The property is in the prospect stage and is developed principally by two 15-foot shafts, cuts, and surface pits. Water is present on the property, and water level is believed to lie at about 100 feet below the surface.

The country rock seems to be the pre-Cambrian granitoid complex. It is intruded by "porphyry" near by. The deposits are contained

principally in a large fissure vein, which strikes north-northwest, and the quartz croppings have a length of nearly 2 miles.

The gangue is principally quartz, and the ore contains copper, lead, silver, and gold. Average samples of the ore collected from an ore shoot about 4 feet in width in the lower part of the two shafts on Siamese claims Nos. 1 and 2 gave assay returns about as follows: Silver, 14 ounces to the ton; copper, 4 per cent; lead, 9 per cent; zinc, 2 per cent. Another test, made of a presumably select sample from the same shaft, though the manner of collection is not stated, is said to have given 10.5 per cent of copper, 16 per cent of lead, and 35 ounces silver and $1.60 in gold to the ton. The ore is said to be good concentrating ore.

GRAND WASH CLIFFS.

MUSIC MOUNTAIN DISTRICT.

GENERAL DESCRIPTION.

Location and history.—The Music Mountain district lies about 25 miles north of Hackberry, in the foothills of the Grand Wash Cliffs. It comprises principally an area about 3 miles in diameter, ranging in elevation from about 3,000 feet at the border of the valley to 4,000 feet on the east. The camp is located toward the southeastern part of the district, near the head of Camp Wash, at about 3,400 feet elevation.

Mineral was discovered here in 1879 or 1880, some of the discoverers and locators being Dave Southwick, Ed Burk, Bill Hatch, and Joe Prisk. Many of the claims began at once to produce. Most of the early work was done by lessees, the ore being treated in arrastres or shipped; later much of it was milled on the ground. The recent history of the camp is practically synonymous with that of the Ellen Jane mine. A chief drawback to the camp has been lack of water.

Production.—Concerning the production of the camp, figures of which are not available, the following data were gathered. Much rich ore was produced by lessees in pioneer times from nearly all the principal veins. At that time the Burk claim, now called the Golden Serpent, produced considerable ore that averaged from $300 to $400 a ton in gold and at present some of its ore contains 7 to 8 ounces of gold to the ton. The Ellen Jane mine in 1892 produced 165 tons of $32 ore, and later a smaller lot of $42 ore. The Lucky Cuss vein and the Marie E. vein are known to have produced considerable, all of which, together with what has been produced by the other veins, probably considerably exceeds $20,000.

Topography and geology.—The surface of the district in general slopes westward into Hualpai Valley (fig. 25). The topography is mostly rough, with several longitudinal ridges locally studded by

cliffs and separated by washes or gulches, some of which head several miles to the east near the summit of the cliffs and the Colorado Plateau.

The country rock is principally granite, which in part belongs to the pre-Cambrian gneiss and schist complex, while the greater portion seems to be younger. The pre-Cambrian rocks are best exposed where they form the core of the ridge just south of the camp. The supposed younger or post-Cambrian granite prevails throughout the greater portion of the district and is especially prominent in North Ridge, northwest of Camp Wash, where it

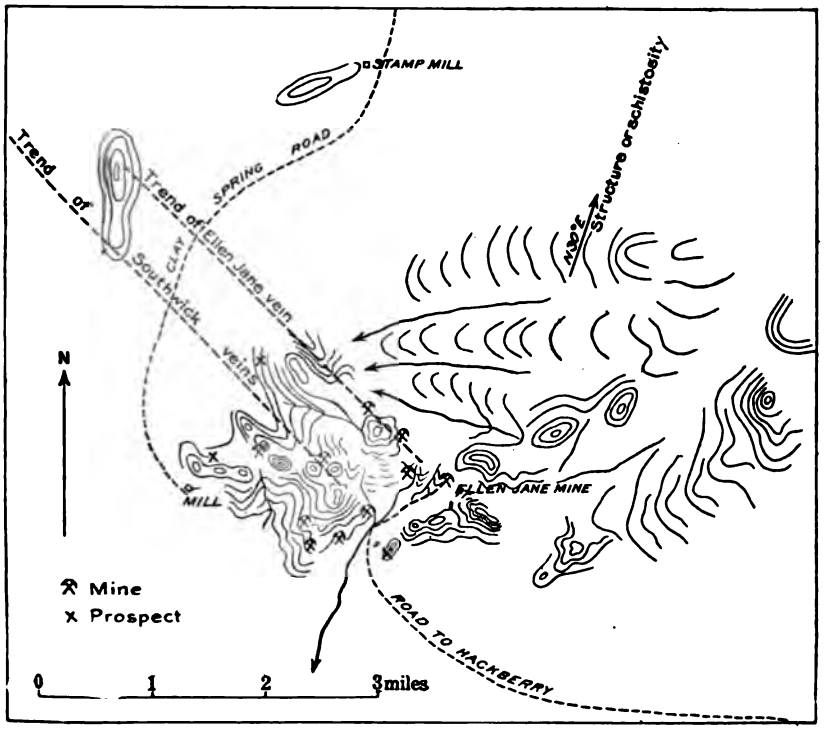


FIGURE 25.—Sketch map of Music Mountain district.

extends to the old mill at the border of the valley on the west. In the northern part of the district it is a relatively fresh-looking medium-grained gray biotite granite, allied to quartz monzonite. In the southern part what is thought to be the same rock is coarse or pegmatitic.

The older or pre-Cambrian country rocks have a well-marked schistosity, which trends about N. 30° E. and dips about 65° SE., and both classes of rocks are cut by a well-marked sheeting that strikes about N. 60° W. with dip about vertical and seems to be decidedly later than the schistosity.

The country rocks are intruded by dikes and masses, both basic and acidic. The most important of the basic rocks is a medium to coarse grained basaltic diabase, which weathers in coarse pieces and nodules and may be of two periods in age. As dikes it is associated with the veins, and as a mass, or possibly a sheet, about 150 feet in thickness, from which the dikes seem to be given off; it trends in a north-south direction across the middle portion of the eastern part of the district and dips eastward into the mountains at angles of about 25°. Remnants of it also in part cap the northeastern part of North Ridge and dip gently to the west.

The diabase-basalt is not affected by schistose structure but is older than the veins and probably also older than the sheeting. It contains fragmentary inclusions of granite and exhibits the other phenomena usually characteristic of an intrusive.

The most important of the acidic intrusives are a coarse granular granite containing much orthoclase, no bisilicates, and no microcline; a fine-grained microcline granite; and a medium-grained purplish-gray granite porphyry. The coarse granular granite is not affected by schistosity and is older than the diabase, probably also than the sheeting. The fine-grained granite is in part schistose, and is earlier than the sheeting, the veins, and the diabase. It may be pre-Cambrian. The granite porphyry is associated with the Lucky Cuss and Southwick veins. It has a micropoikilitic groundmass of quartz and orthoclase and contains phenocrysts of oligoclase, andesine, and biotite. It has no schistose structure and is earlier than the diabase. At the Lucky Cuss mine it seems to be earlier and at the Southwick mine later than the vein deposits.

Deposits.—The deposits are chiefly quartz fissure veins, which in the main dip steeply to the northeast. The principal ones are the Ellen Jane, Lucky Cuss, and Southwick. The Ellen Jane vein lies in the eastern part of the district and has a length of about a mile and a known vertical range of about 600 feet. (See fig. 25.) Its croppings range in elevation from about 3,430 feet in the head of Camp Wash to about 4,000 feet on North Ridge. The vein is best developed in the Ellen Jane mine. Some of the veins may be found to continue in a northwesterly direction underneath the heavy wash of the valley.

About 6 miles east of Music Mountain Camp, at the head of Clay Springs Wash, near the summit of the Grand Wash Cliffs and the Colorado Plateau, deposits of iron ore of considerable extent are reported to occur. The iron ore is locally stained by copper. These deposits seem to lie in the Carboniferous limestone.

ELLEN JANE MINE.

Location and history.—The Ellen Jane mine practically coincides horizontal extent with the Ellen Jane vein; the main shaft is

situated on the southeastern part of the vein at the head of Camp Wash, about one-eighth of a mile east of Camp, at an elevation of about 3,440 feet. The Ellen Jane claim, on which the main shaft is situated, was discovered and located in 1879 or 1880 by Joe Prisk. It soon became a producer, being at first worked by lessees, and a little later it was owned by W. F. Grounds, of Hackberry, who about 1886 sold it, together with the Tomonotta adjoining it on the west, to the Gold Mining Company, of Washington, D. C., of which General Rosecrans was a member. The company at once became the moving spirit of the camp and installed a 4-roller 8-ton mill, which still stands at the foot of the mountains about 1½ miles west of the camp. The mill is stated to have saved about three-fourths of the gold, but left about $9 a ton in the tailings, owing to the fact that some of the ore was not free milling. About 700 tons of ore were

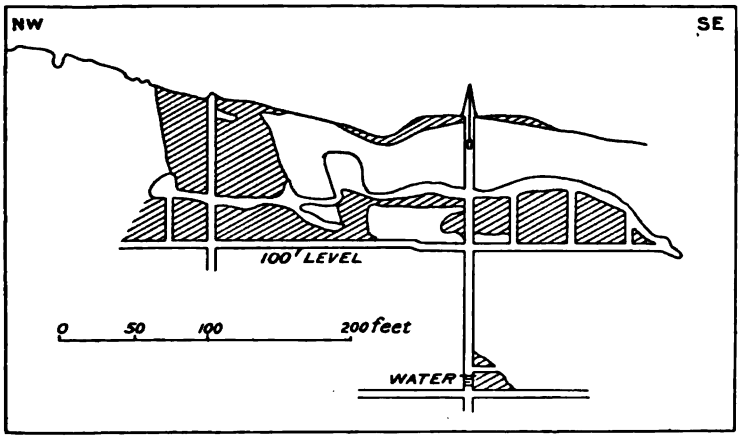


FIGURE 26.—Longitudinal section of Ellen Jane mine, showing stopes.

put through this mill and a considerable amount through the 4-stamp mill later installed by Mr. Grounds at Clay Springs, 2½ miles north of Camp. This mill is supplied with water from springs in the upper part of the cliffs.

Later the company was reorganized as the Washington-Meridian Company, repaired and improved the mill, mined some ore, and then temporarily closed in the spring of 1903. In the spring of 1904 operations were resumed, but as the water supply failed the company ran in debt, and the mine was sold to William Grant, of Hackberry, who in the spring of 1906 bonded the property, including seven of the most important contiguous claims of the camp, nearly all situated on the Ellen Jane vein, to P. C. Friend, of Philadelphia. Some gold has been produced during the last few years by lessees.

Developments.—The mine has about 1,500 feet of work (fig. 26). On the Ellen Jane claim it is developed to a depth of 200 feet, prin-

cipally by a main shaft and two levels containing about 300 feet o drifts; to the northwest, on the Tomonotta, Cleveland, and World Fair claims, it is developed principally by adit drifts, shafts, winze and stopes, aggregating about 700 feet of work. The southern dri on the Cleveland is 300 feet long and the northern one on the san claim about 200 feet, its face being within 200 feet of that of th southern drift, but at a considerably lower level.

At about 400 feet below the top of North Ridge where the vein ou crops and the Cleveland workings occur, at the edge of the wash, crosscut tunnel, known as the Wilsie tunnel, has been started to t the vein at greater depth. This tunnel now has a length of 150 fe in solid granite and will have to be driven about 300 feet farther reach the vein.

The main shaft near camp now contains water up to about t 180-foot level, and produces about 5 barrels of good potable wat a day. Before water was encountered in the mine the supply for t camp had to be hauled, and during part of the time was brought fro springs situated near the head of Clay Springs Wash, about 6 mil distant.

Deposits.—The Ellen Jane vein lies in granite, chiefly in the su posed post-Cambrian granite. It strikes about northwest and di to the northeast at angles of about 80°. It varies from 2 to 7 feet width, the average being about 4 feet, and is usually separated fr the walls by a few inches to a foot or more of red and green, mu slickensided gouge. A diabase dike is associated with the vein a shares its fissure.

The gangue is principally normal vein quartz, crushed and part brecciated, together with highly crushed and altered gran and diabase, locally banded and all oxidized and iron stained to bottom of the mine.

The ore is up to 3 feet and averages about 5 inches in width. holds fairly constantly to the hanging-wall side of the vein and mill runs is said to average from $10 to $42 in gold to the ton; shipping ore runs as high as $500 a ton. A microscopic section it shows principally granular quartz, iron, and limonite.

At the main shaft on the Ellen Jane claim the development principally on the 100-foot level, on which the drifts extend ab 130 feet to the southeast of the shaft and about the same distance the northwest. The vein contains from 1 to 2 feet of breccia an mixture of crushed granite and some diabasic material and qua all mashed together, on the foot-wall side, and about the same thi ness of material, mostly of granitic origin, with some quartz, on hanging-wall side, between which and the granite wall itself is fr 3 inches to a foot of intervening gouge.

The diabase dike which, at the surface just southeast of the shaft, is associated with the vein on the hanging-wall side, is on this level on the foot-wall side and for the most part forms the foot wall with 1 foot or more of highly slickensided gouge intervening between it and the vein.

On the second or 200-foot level but little work has yet been done, probably owing to the fact that sulphide ore appears here; northwest of the shaft occurs a foot of ore that contains considerable galena and iron pyrites. This is the only base ore found in the vein. It averages about $18 a ton. About 10 feet above the floor of this level, in a small stope, the vein is about 3½ feet thick and is marked near its middle by a sharp line denoting the contact plane of its two facing halves, and along this line and locally diverging from it at sharp angles are ¼-inch to 2-inch seams of red ore, said to average $300 to $400 in gold to the ton.

On the whole the vein, so far as seen in the bottom of this part of the mine, does not look very promising. A generalized section of it is shown in figure 27.

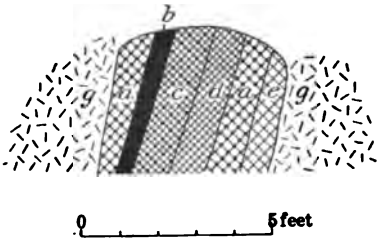


FIGURE 27.- Section of Ellen Jane vein at bottom of main shaft. *a*, Gouge, red, brown, and green stained; *b*, ore shoot, dark-red or light-gray carbonate; *c*, vein material of chiefly granitic origin and some quartz; *d*, vein composed of a mixture of altered country rock granite, leached diabase, quartz, etc.; *e*, diabase dike, foot wall; *g*, granite, country rock.

To the northwest, on the Tomotta and Cleveland claims the south drift has a length of 300 feet. More or less throughout this extent the vein is associated with the diabase dike, which, just outside the drift in the cut along the tram track, lies for about 330 feet on the foot-wall side of the vein and is about a foot in width, but which enlarges in the drift. In the mouth of the drift the dike obscurely forks across the vein to the hanging-wall side or vice versa. Locally, the dike and vein interlace and fine seams or stringers of ore occur in the dike overhead. The face of the drift, which is about 200 feet below the surface, is occupied largely by the diabase dike, which is here 2½ feet thick. On its hanging-wall side 1 foot of crushed or brecciated dike material carries the ore. This material is probably composed of crushed and altered granite and diabase with but little quartz, all altered almost beyond recognition.

Similar material, but with quartz disposed in narrow bands or stringers, also occurs on the foot wall, but, although it appears to be an important part of the vein, it does not carry much pay.

A cross section of the vein at the mouth of the drift, from foot wall to hanging wall, is as follows:

Cross section of Ellen Jane vein at mouth of drift.

	Ft.	In.
Brecciated gouge, composed of granitoid material, some quartz, and possibly altered diabase, all stained yellowish and reddish; it seems to carry the ore		9
Bands and stringers of material similar to the above, but less stained; at 4 inches from hanging-wall side a median seam, containing comb quartz	1	6
Diabase dike, sheeted longitudinally into slices ½ to 2 inches thick	1	
Dull-greenish altered diabase		1
Impure quartz		1
Sheared material at granite and diabase contact, more or less heavily stained		1-2

On the northern part of the Cleveland claim, near the top of the ridge, the Ellen Jane vein is joined by the Contention vein, which comes in from the south at an angle of about 30°. Although the Contention has not here its normal size, being wavy and locally pinched, it nevertheless very materially enriches the ore at the junction.

On the Tomonotta claim the ore mined in late years by lessees averages about 8 ounces in gold to the ton, while higher up in the upper part of the North Ridge portion of the Ellen Jane vein, including the Contention vein, the ore on the whole averages $100 in gold to the ton. Common shipping ore from the Ellen Jane vein now runs about $30 a ton, and it costs about $6 a ton to deliver it to the railroad at Hackberry.

CONTENTION VEIN.

The Contention vein is situated on the east top of the North Ridge, where it joins the Ellen Jane mine. It strikes about N. 30° W. and dips steeply to the west-southwest. It has been worked by shallow shafts on the Contention claim. Its surface workings are principally in a remnant of the diabase sheet, which is here 8 or 10 feet thick and in part caps the ridge.

MARIE E. VEIN.

The Marie E. vein is a small vein or stringer which lies about 200 yards northeast of and nearly parallel with the Ellen Jane vein and stands about vertical. It has been worked to a considerable extent, principally in the diabase, by cuts and drifts, to a depth of 150 feet. It consists for the most part of a thin sheet of reddish dense crushed and altered rock material, seemingly diabase, and a little quartz 5 or 6 inches in width filling a narrow fault fissure and containing $300

in gold to the ton. It is usually frozen to the walls of the country-rock diabase, where it leaves a ragged wall surface when broken off. It has been worked downward through the diabase and has about the same width and carries about the same values in the granite as in the diabase. The associated minerals are iron oxide and a small amount of calcite occurring in crystalline incrustations. The production of this small vein is considerable. At a point toward the west a claim worked by windlass produced several carloads of good ore.

LUCKY CUSS VEIN.

The Lucky Cuss vein lies southwest of and nearly parallel with the Ellen Jane vein. It is exposed on the Lucky Cuss claim, situated just southeast of the Ellen Jane vein, where it has been developed interruptedly for about one-eighth of a mile and locally to a depth of 150 feet. It lies chiefly in the red pegmatitic granite and seems to be stronger there than in the diabase, which it cuts in places on the southwest. On the north end of the claim the granite is intruded by a granite porphyry dike 8 or 10 feet in width, which is in contact with the vein or what may be a spur or stringer given off by it. The dike seems to be older than the vein. The vein strikes about N. 52° W., with dip steeply to the northeast or vertical, and is disturbed by a fault of about 25 feet lateral throw. It is 2 to 2½ feet thick and is composed principally of granitic material and quartz stained by iron and manganese, all more or less closely banded. The quartz shows comb structure.

The ore contains principally silver and some gold and is mostly of high grade. The production has been considerable on the Lucky Cuss claim, where the oxidized portion of the vein seems to be mostly worked out but is reported to contain still some good ore.

To the northwest the vein is supposed to cross Camp Wash beneath the camp, beyond which and where it ascends the south face of North Ridge it has been opened by a series of adit drifts and cuts. Here also it has produced low-grade ore containing considerable galena.

SOUTHWICK VEIN.

The Southwick vein is about half a mile southwest of the Ellen Jane vein. It strikes northwest and seems to extend about a mile. It is developed principally to the north of Camp Wash in the south slope of North Ridge, interruptedly for about one-fourth of a mile and locally to a depth of 100 feet within a vertical range of about 400 feet, extending from 3,100 to 3,500 feet in elevation. It lies in the granite and is associated with the granite porphyry and younger diabase dikes described on page 144. The vein appears best where adjoined by the diabase dike.

The gangue is usually iron-stained quartz and the ore contains gold, some silver, oxide of manganese, and considerable hematite.

LOST BASIN DISTRICT.

The Lost Basin district is situated in the most northern part of the region examined. It comprises the belt lying between Hualpai Wash on the west and Pierce Mill Canyon on the east, and extending from Colorado River at the mouth of the Grand Canyon southward through the Grand Wash Cliffs to a point 12 miles beyond Scanlon Ferry, near the latitude of Gold Basin. It has a length of 20 miles and a width of about 9 miles. It is reached by wagon road descending Hualpai Wash from Gold Basin to Colorado River at Scanlon Ferry.

The principal veins occur south of the middle of the belt, about 7 miles northeast of Gold Basin, where, between elevations of about 2,000 feet on the west and 5,000 feet on the east, they trend about east and west across the district for a distance of 6 miles.

They were discovered about 1886, and considerable ore has been taken out from time to time and treated in arrastres or milled, but the ground on the whole is but little more than prospected. This is probably due to the lack of water. The nearest water supply is Colorado River at Scanlon Ferry, 8 miles to the north, whence water is now hauled at a cost of $2 a barrel. The two points, however, could be readily connected by pipe line.

The ore could without difficulty be hauled to the river, with which the area is said to be connected by a good wagon road, but its transportation by water down the river, advocated by some, does not seem feasible, owing to the dangerous rapids that would be encountered and the impracticability of bringing barges or bottoms of any kind up the river and the great cost of bringing them overland.

The deposits are mostly owned by about half a dozen men. They occur mainly in the pre-Cambrian granitic rocks in well-defined, strong quartz fissure veins, of which there are two sets. Those on the west strike northward with dips vertical or steep to the east and are chiefly gold bearing; those on the east strike west-northwest and are chiefly copper bearing. The relative age of the two sets of veins has not been determined, but it is possible that the copper deposits may be in part pre-Cambrian.

The principal gold properties are known as the Scanlon-Childers mines and are owned chiefly by Mike Scanlon, of Basin, and Cy Childers, of Kingman. The veins average from 4 to 6 feet in width. Several of them are reported to be from 10 to 14 feet in width and from 1 to 2 miles in length. The croppings are principally brown and green iron and copper-stained quartz and are in part prominent.

Some of the veins are said to be exposed in the canyons to a depth of 200 feet or more and yield good shipping ore from the surface down to this depth. The ore contains principally gold and silver and a little copper, but no copper of commercial value and not enough to interfere with cyaniding.

The ore on the whole is fine in texture. It has been sampled and tested by Denver men and was found to be excellent cyaniding ore, and is reported to contain on the average $8 or upward in gold to the ton.

The copper deposits are said to extend from a point near the middle of the belt nearly to the summit of the Grand Wash Cliffs and Colorado Plateau on the east. They are owned chiefly by James Burrows and J. W. Mouat, of White Hills. Other owners are Messrs. Grant, Fielding, and Roseborough, of Hackberry. The pre-Cambrian complex is here more schistose than on the gold-bearing side of the belt, and some of the deposits on the extreme east are said to be associated with limestone. The copper-bearing veins, as indicated, strike west-northwest at nearly right angles to the gold-bearing veins. The croppings are large, and, as seen by the writer, consist principally of oxidized masses of brown and black quartz, with some malachite and azurite. The ore contains principally copper and carries also some gold and silver. Some of it is reported to have assayed from 17 to 20 per cent of copper.

The production of the district is reported to be many thousand dollars, chiefly in gold.

BLACK MOUNTAINS.

INTRODUCTION.

The deposits of the Black Mountains differ in most respects very markedly from those of the Cerbat Range. They occur chiefly in the Tertiary volcanic rocks. Their trend is west-northwest to northwest, the dip steep. Their gangue is mainly calcite and dolomitic carbonates, but these minerals have largely been replaced by quartz and adularia, a variety of orthoclase free from sodium and with characteristic crystal form. They are deeply oxidized and, as a rule, contain no sulphides, and their values are almost exclusively in gold, there being usually no base metals present. There is a general absence of fluccan or gouge, the veins being usually frozen fast to the country rock.

The districts in the Black Mountains, named in order from north to south, are the Eldorado Pass, Gold Bug, Mocking Bird, Virginia, Pilgrim, Union Pass, Gold Road, Vivian, and Boundary Cone. Of these the most important is the Gold Road district. The two first

named are in the Eldorado Pass mining district, the two next are in the Weaver mining district, and the Gold Road and Vivian in the San Francisco mining district.

GOLD ROAD DISTRICT.

GENERAL OUTLINE.

Location.—The Gold Road district lies about 24 miles southwest of Kingman, mainly on the west slope of the mountains. It extends from Meadows, on Meadow Creek, at the east base of the range, northwestward to the Moss and Golden Star mines, about 6 miles beyond the crest. It has a length of about 10 miles and a width of about 4 miles. The principal camp, local supply point, and center of activity is Gold Road, situated on the western slope of the range, about 1 mile from the crest, at about 2,900 feet elevation and at the head of Silver Creek. It is 16 miles northeast of Needles, Cal., and is reached by wagon road from Kingman, via Gold Road (formerly Sitgreaves) Pass. Gold Road (Pl. IX) has a population of about 350. It is equipped with modern improvements, is well kept, and is plentifully supplied with excellent water pumped from Meadows.

History.—Mineral was first discovered in the district early in the sixties by John Moss and party, who found rich gold ore at what has since been known as the Moss mine, 4 miles northwest of Gold Road, near the old Camp Mohave trail. About the same time, or a little later, the Miller mine, formerly known as the Parsons mine, and especially as the Hardy mine, 2 miles northwest-west of Gold Road, was discovered, and for a long time these two mines were the principal properties in the district. They were at once worked and soon began to produce, the ore being at first shipped or milled in arrastres, and a little later some of it was treated in the Moss mill, which was built on the Colorado at the mouth of Silver Creek, about 7 miles west of the Moss mine.

A decade later, owing to the discovery of rich silver-gold ore in the Cerbat Range, the district became and for a long time remained quiet, until the decline in the market value of silver stimulated gold mining. The present activities began with the opening of the Gold Road mine and vein about 1902.

Topography and drainage.—The district ranges in elevation from 2,000 feet on the west and about 3,000 feet on the east to 4,500 feet at the top of the range. The range portion, which is about 3 miles in width, is rugged, particularly on the west, being marked by precipitous fault scarps, deep gulches, and canyons. Here in a horizontal distance of about 1½ miles the surface falls off from 4,500 feet elevation at the crest to 2,500 feet on Silver Creek just below Gold Road. The remainder of the area consists mainly of low, rounded, outlying

GOLD ROAD MINE, MILL, AND CAMP, LOOKING SOUTHEAST.

mountains or hills, open washes, and gravel-covered gentle slopes or mesas.

The principal outliers are the Hardy Mountains, a low group situated on the southwest about 3 miles west of Gold Road, to the south of Silver Creek. They are about 3 miles in diameter and rise about 600 feet above the surrounding country. Two miles north of the Hardy Mountains and Silver Creek is a much smaller group—the Moss Hills. On the east the drainage flows principally by way of Meadow Creek into Sacramento Valley, and on the west through Silver Creek into the Colorado.

Geology.—Tertiary volcanic rocks prevail, particularly in the eastern or range portion of the district. They practically constitute the range, and are in places covered by rhyolite and younger basalt. On the west occur also local areas of the pre-Cambrian gneisses, syenite, granite porphyry and micropegmatite, greenstone agglomerate, and overlying sheets of supposed Tertiary conglomerate and younger gravel and lava flows.

Deposits.—The deposits, which number about a dozen, are chiefly gold-bearing fissure veins or lodes. They occur in the lower part of the undifferentiated volcanic series, the green chloritic andesite, and the granite porphyry and micropegmatite described on page 31, and also along certain of their contacts, where rhyolite is usually the intrusive. They consist of two main types—those in which the gangue is chiefly quartz and adularia and those in which it is chiefly calcite. The former, which seem to be the older and carry the best values, occur mostly in the undifferentiated volcanic rocks and in granite porphyry and have a general northwesterly or northwest-westerly trend; the latter occur mainly in the green chloritic andesite and trend nearly north. The most important of the former type is the Gold Road vein; of the latter, the Pasadena and Mossback veins. (See Pl. X.)

The veins in the green chloritic andesite in both the Gold Road and Vivian districts occur mostly in fissures, which seem to be peculiar to this formation and do not as a rule penetrate the underlying older andesite. The origin of the metallic contents was due to thermo-aqueous processes. In general the quartz and values favor the hanging wall, where the quartz feeds in by oblique stringers, and the spar or calcite favors the foot wall.

GOLD ROAD MINE.

Location and history.—The Gold Road mine, the most important in the district, is situated at Gold Road, on the western rugged slope of the range about 1 mile below the crest, at an elevation of about 2,900 feet, on the western part of the Gold Road vein. From its

croppings the Gold Road vein has long been known, but the discovery of mineral values and the locations which resulted in the mine were made about 1902 by Joe Jeneres, a Mexican prospector, who was grubstaked to the amount of $13 by Henry Lovin, of Kingman. The discovery is reported to have been accidental. Jeneres in searching for his burros, which had strayed from camp, happened to pick up, near the present site of the Gold Road mine, a piece of quartz showing free gold, which led him to set up a monument and stake the Gold Road claim. Reports in Kingman that the specimen found by Jeneres and the croppings assayed 40 ounces in gold to the ton brought about a stampede to the district and the staking of many claims. Jeneres and Lovin did their assessment work and, with developments confined to a shaft 15 feet deep on the Gold Road claim, bonded the property to Los Angeles men for $50,000. Later the property was sold to Joseph Burkhardt, who worked it for some time and then sold it to Posey, Bailey, and McCormick for $275,000. Posey soon capitalized the property, enlisting the money of a French syndicate, which is currently reported to have paid half a million dollars for one-fourth of the stock. Work has been carried on systematically by this company, and the mill has been in operation about three years. The property, now including 12 or more claims, covering practically the entire known length of the Gold Road vein and distributed approximately as shown in Plate X, is now owned by the Gold Road Mining and Explorations Company, and is reported to have paid dividends of 5 per cent on a capitalization of $1,500,000. The company is incorporated under the laws of Arizona, with headquarters at Los Angeles and Paris. The company's annual reports are printed in parallel columns in English and French. It employs 180 men, of whom 75 to 80 work underground in three eight-hour shifts. Miners are paid $3.50 and machine men $4 a day. The company's pay roll is about $16,000 a month.

Developments and equipment.—The mine is developed to a depth of 800 feet by a main shaft and eight (1908) levels aggregating about 3,000 feet of drifts. Most of the ore has been mined for a distance of about 240 feet to the east and 640 feet to the west of the shaft, about as shown in the accompanying section of the underground workings (fig. 28). From the surface to the 300-foot level the shaft inclines at an angle of 85°, below which it is vertical and ends in a sump 35 feet below the 800-foot level. The levels are spaced 100 feet apart. The method employed in mining is a system of overhead stoping. The entire vein between the two levels is mined and the broken ore left in the stopes, from which it can be drawn as desired through chutes located 12 feet apart.

The mine produces about 12 gallons of water a minute. The water was first encountered on the 200-foot level in about the same amount it now occurs in the mine.

The principal surface equipments are a 50-horsepower steam hoist and a 200-ton gyratory crusher, located at the mine and run by separate engines; and a very complete milling plant, consisting essentially of six Huntington mills equipped with rollers, settling tanks, vats, laundries, filter presses, etc., and having a capacity of more than 200 tons of ore a day. The mill plant engines, including those that run the mills, compressors, and mine pump, and generate electricity for lighting the town and mine, aggregate about 500 horse-

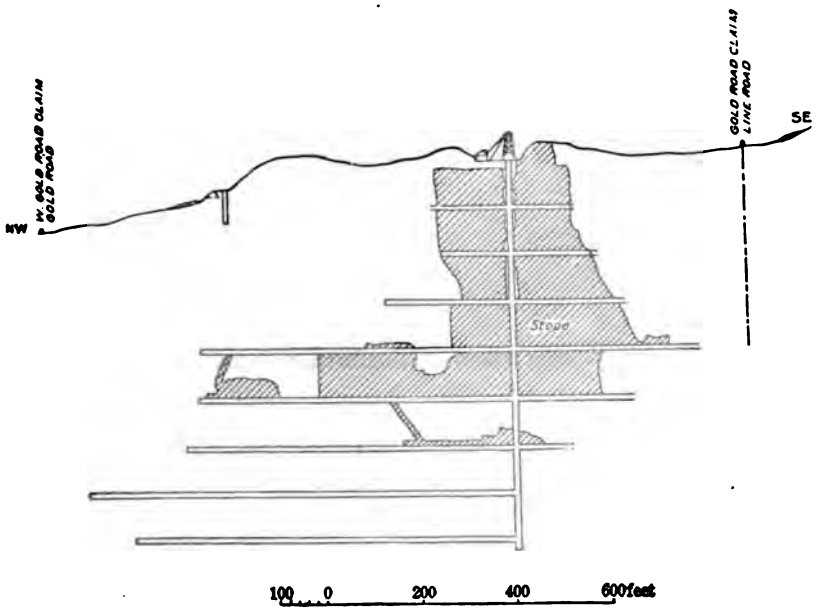


FIGURE 28.—Longitudinal section of workings on vein of Gold Road claim, Gold Road mine.

power. The mills and the pump are run by electric motors, with power transmitted from the generating plant in the engine room. In all, the engines of the mine and mill aggregate about 700 horsepower.

The principal source of the power, especially in the generators, is California fuel oil, freighted by wagon from Kingman and delivered at a cost of about $3.50 a barrel. Refined oil and gasoline used in some of the smaller engines are proportionately more expensive. The company's fuel bill for the year 1906 was $96,000.

The mine was closed at the end of 1907 on account of the high cost of power and the low grade of the ore. It was decided to open the east part of the property and connect it with the Gold Road claim by a drift on the 500-foot level. This drift has been extended 1,000 feet east of shaft No. 1. Shaft No. 2, to connect with this

drift, is being sunk at the junction of the Billy Bryan and Line Road claims. The total depth of this shaft will be 750 feet. It was lately reported that the Gold Road mines are being supplied with electric power by a large plant recently installed at Kingman, and that a 40-stamp 300-ton cyanide mill is being erected.

Ore treatment.—The ore is nearly all of milling quality, averaging about $10 in gold to the ton. The gold is extracted in the plant which has been described, the method of treatment being by Huntington mills and the cyanide process. Of the six mills five readily handle 180 tons of ore a day, one mill being usually held in reserve.

The ore is first crushed to less than 1½ inches in size in the gyratory crusher at the mine, whence it is conveyed by tram cars to the mill plant. Here it is further reduced by rolls to ¼-inch mesh or less before it goes to the Huntington mills, where it is ground in cyanide solution to less than 50 mesh, about two-thirds of the product being sand and one-third slimes, the slimes resulting chiefly from the calcite content of the ore. The sands are settled in vats and tanks and the slimes are filter pressed. The gold is precipitated on zinc shavings and refined at the mine.

The ore is easily milled and treated, although fine crushing is necessary as the gold is so finely disseminated in the quartz. Twenty-five per cent of the gold is liberated in two or three hours, and 85 per cent in ten days percolation. It is stated that by fine grinding 98 per cent of the gold can be extracted. The usual saving is said to be 91½ per cent of the assay value. The small residue left in the tailings is not entirely lost, for in the gulch below from $30 to $50 worth of gold is daily collected by precipitation from the seepage of the tailings dump. The output is shipped bimonthly in gold bricks worth about $45,000 each.

The ore is now said to be mined at a cost of $2.50 to $3 a ton and mined and milled at a cost of about $5 a ton, allowing $8 ore to be handled with a good profit. With the installation of cheaper power and a more efficient mill ore of much lower grade might be worked. The management hopes to reduce the cost eventually to about $3.50 a ton. Plate amalgamation was tried, but without much success.

The cheaper power might be supplied from a large electric plant at Kingman or by the installation of a large steam-power plant with engines of high efficiency, now considered by the Gold Road Company on its own ground. In this latter event the fuel oil now freighted by wagon from Kingman could be pumped from Meadows over the range much more cheaply than it is now freighted over.

The water used in operating the mill, besides that produced by the mine, is derived from the company's well at Meadows, on the east slope of the range, whence it is pumped by a 12-horsepower gasoline engine to the camp and mine. A small spring has been known at

Meadows since pioneer times, when the place was used as a station for the government's desert camel pack train, but the presence of water in copious amount was first discovered by the Gold Road Company by sinking a shallow well in the rhyolite where the Meadow Creek valley is crossed by a strong diabase dike. This seems to form a subterranean dam and raises the underground water to the surface as it percolates down the slope of the range through the rhyolite tuffs, producing in this locality a large supply.

About the only loss of water in milling is that which is hauled out in the tailings on the cars. The remainder, having brought the ore in solution through its several stages of treatment, is pumped back to the mill, whence it starts out with a new charge of fresh ore and thus moves in a cycle, being used on different charges of ore over and over again.

Production.—The production of the Gold Road property, including the Billy Bryan claim, to the end of 1907 is reported to be about $2,250,000, most of which was produced during 1905 and 1906. The production includes 110 tons of shipping ore, amounting to $110,000, derived mostly from the Billy Bryan claim. It was reported late in 1909 that there were in sight on the property 50,000 tons of ore averaging about $12 a ton.

Topography and geology.—The rough topographic features of the district are those characteristic of rapid erosion of heavy volcanic sheets. They consist in the main of broad and rugged westward-sloping, cliff-studded or stepped ridges separated by deep gulches that form the head of the Silver Creek drainage. The camp is situated mainly on one of these ridges and the Gold Road vein lies in the gulch adjoining it on the south.

The country surrounding the mine is occupied by heavy sheets of volcanic flows. The series comprises andesite, trachyte, latite, rhyolite, and dacite, and is nearly 2,000 feet in thickness. This aggregation is difficult to separate and has been referred to above as the "undifferentiated" flows. It extends from a point about 1,000 feet west of the Gold Road mine eastward nearly to the crest of the range. On the west it gives way to the underlying green chloritic andesite, which in the West Gold Road mine, situated near the contact, has been penetrated to a depth of 455 feet. On the east it is overlain by the upper rhyolite. The contact on the west is probably a fault contact, as some of the green chloritic andesite occurs in the Gold Road mine. The structure is a very pronounced close sheeting, which strikes N. 40° W., with vertical dip. The series is intruded by dikes of rhyolite and the younger dark andesite. Much of the rhyolite carries gold values. A dike of it, varying from 12 to 50 feet in width, located about 600 feet south of the mine, is staked and much of it is said to average from $5 to $6 in gold to the ton, the values

occurring chiefly in stringers of quartz and calcite contained in the dike. Near by a portion of the dike is faulted laterally by a throw of 80 feet, which seems to affect the Gold Road vein also. Nearly a mile southeast of the mine, on the Railroad claim, what seems to be this same dike is in association with the vein, its cropping here forming a wall 20 or 30 feet high.

Deposits.—The Gold Road vein extends from a point about 700 feet west of the mine beyond the crest of the range, a distance of nearly 1¼ miles.

The vein strikes about N. 50° W. and dips about 80° N., approximately parallel with the close sheeting in the country rock. It varies in width from a maximum of 22 feet on the west to less than a foot on the east, where it seems to pinch. Between the bottom of the Gold Road mine and the crest of the mountains it has a known vertical range of about 1,850 feet, and its croppings, which, as noted, lie principally in the deeply cut Gold Road gulch, have a vertical range of about 1,300 feet. They consist essentially of iron and manganese stained quartz, silicified rock, and calcite. They are usually prominent, and in places form conspicuous buttes or knobs rising 20 or 30 feet above the surface, as at the Gold Road mine (Pl. XI). Here the hard silicified croppings on both sides of the vein have a lateral extent of 20 to 60 feet. The best ore usually underlies these prominent croppings, which seem to represent courses along which mineral-bearing solutions circulated more freely than elsewhere. The operators also report an intimate association of the ore and the present watercourses in the Gold Road mine. Where the croppings weaken or break down the underlying portion of the vein on all levels tends to become lean or barren, though the fissure and its walls and fillings continue unchanged. An exception to the rule, however, that the strongest croppings indicate the richest ore beneath them, occurs on the middle part of the Billy Bryan claim, described on page 165.

The vein consists essentially of quartz and adularia, with some calcite and brecciated rock, and is more or less banded. With small exceptions it is all good milling ore from wall to wall. The amount of waste, as shown by the small dump at the mine, is almost nothing. The gold, as seen microscopically, and in places by the naked eye, is very finely disseminated, principally in the quartz and adularia. The free gold is said to occur chiefly from the Line Road shaft eastward. The vein is strongest on the west, where, as developed in the Gold Road mine, it is uniformly about 10 feet in width. It is usually in sharp contact with well-defined firm walls of the country rock, consisting of andesite, trachyte, latite, or rhyolite. It is in general frozen to the walls and is locally enriched by oblique stringers that join it at acute angles from the northwest on the

A. GOLD ROAD MINE, LOOKING SOUTH.

Silicified lode croppings on both sides.

B. GOLD ROAD GULCH, LOOKING SOUTHEAST FROM UNITED STATES MINERAL MONUMENT.

Vein croppings in shade to the right.

hanging-wall side. As a rule hard and rough walls in this mine indicate good ore, and conversely soft and smooth walls are apt to correspond with lean ore. The ore consists chiefly of fine-grained, light-greenish quartz, much of it bladed or hackly and with a peculiar chalcedonic or drusy appearance (Pl. II). Many of the blades of pseudomorphic quartz are thickly covered with minute quartz crystals. Microscopic adularia is commonly intergrown with the quartz. Much of the quartz is clearly pseudomorphic after calcite. The quartz and adularia are locally present in equal amount, but more commonly in the ratio of about 2 to 1. As a rule no sulphides are present and but little limonite. Some pyrite occurs in the wall rock in the lower part of the mine, but no sulphides save that on the 600-foot level (see p. 162) have been found in the ore, nor are there indications that they were ever present.

In recent years the work in the Gold Road mine has mostly been below the 300-foot level. When the Gold Road Company acquired the property the shaft had been sunk to this level, but, except a few sacks of high-grade ore which had been shipped, no ore to speak of had been stoped. The lowest-grade ore yet taken out of the mine was obtained between the surface and the 300-foot level, where it fell to $5 a ton. The ordinary mill run, it is said, rarely falls below $8 or $9 and ranges from that up to $22 a ton. It averages about $10 a ton, but $100 ore and upward is occasionally encountered on the hanging wall, where all the high-grade ore occurs. The pinching of the vein on the 300-foot level about 1903 led to the apprehension that the mine was worked out and would have to be abandoned. A dry-crusher mill was accordingly installed to work out the ore then in sight to this depth. In the mean time, however, the shaft was sunk 100 feet deeper. The ore not only continued down, but improved with depth. Then came the demand for a better mill, and the present Huntington mills were installed because the dry crusher could be used in connection with them and the immediate demands more readily and cheaply met. A sketch of some of the more important features of the deposits noted on the principal levels follows.

On the 300-foot level the walls in the main are firm and the country rock is an andesite, that on the hanging wall being the more-altered variety. In both walls a younger intrusive andesite appears in places. This is also considerably decomposed and contains chlorite and calcite. Locally the foot wall is softened and the soft spots are mineralized and carry low values, while the firm walls are barren. On this level the vein contracts, and between this and the 400-foot level it pinches to but 2 feet in width and is not workable. The striations on the walls dip 65° SE. About 400 feet west of the shaft, at the upraise from the fourth level to this level, the vein is composite,

about 8 feet in width, and is constant and continuous from this point down to the sixth level. A section of the vein sketched on this level, in which the best ore-bearing portion is the green quartz, follows:

Section of vein on 300-foot level, Gold Road mine.

	Ft.	In.
Hanging wall, gray andesite with dip slightly abnormal.		
Crushed greenish quartz ore	2	6
Fine-grained dark andesite, dike (?)	1	6
Andesite with stringers of quartz ore	1	
Quartz ore containing strips of andesite	1	
Good quartz ore with some crushed andesite	2	
Foot wall, gray andesite, partly mineralized with some quartz.		

On the 400-foot level the country rock is altered and shattered chloritic andesite and, as shown in the hanging wall in the crosscut at the pump just north of the shaft, is cut by a network of stringers and veinlets of quartz. The hanging wall, as seen 300 feet west of the shaft, consists in part of more or less silicified, banded, altered reddish lithoidal rhyolite containing parallel veinlets of chalcedonic quartz and is typical of the rock that usually occurs in the hanging wall in association with high-grade ore throughout the mine. At 400 feet west of the shaft the foot wall includes an altered andesite containing epidote, chlorite, and pyrite, resembling that found in the bottom of the mine on the 700-foot level, above which, as currently believed and reported, no sulphides had ever been found. The pyrite is very fine grained and is profusely and evenly disseminated throughout the rock. On this level the vein is similar to that on the 300-foot level above described. To the west it is reported to contain three distinct shoots, and, as elsewhere in the mine, it is the greenish quartz and not the spar (calcite) which carries the gold. The calcite prevails toward the foot wall, and the quartz and consequently the values associated with it favor the hanging wall. Wherever the hanging wall straightens up or is slightly overturned and dips to the southwest or toward the foot wall it does not carry any values.

On the 500-foot level at the shaft the following partial cross section is shown:

Cross section on 500-foot level, Gold Road mine.

	Feet.
Andesite	15
Quartz-calcite vein dipping northeast	7
Andesite	5
Vein	8
Hanging wall containing rhyolite.	

At 75 feet west of the shaft the walls are vertical or slightly overturned, and the foot wall contains reddish-brown, brecciated, mineralized rhyolite similar to that described on the 400-foot level, but coarser and less banded.

At about 100 feet west from the shaft the 7-foot stringer exposed at the shaft landing gradually joins the vein at a sharp angle on the foot-wall side and doubles the values in the vein, and the walls and the vein here gradually assume their normal dip of 86°. Just beyond this locality the vein increases to 10 feet in width, and at about 200 feet west from the shaft it is about 22 feet wide, the entire vein being good ore. The width diminishes somewhat upward toward the 400-foot level.

At about 200 feet west of the shaft a 4-foot stringer leads off at a sharp angle to the west, and both stringer and intervening mineralized rock wedge are worked with vein to a point where the wedge becomes several or more feet in thickness. Here the stringer affected the values of the vein but little, but just beyond the junction of the stringer the ore gradually enriches to $80 a ton, and this value for the full 8-foot average width of the vein continues 100 feet westward to a fault or break, and with but slight decrease extends upward to the 400-foot level. On the whole the enrichment seems due principally to stringers feeding in from the ragged hanging wall at acute angles from the northwest along the structure or sheeting. In this rich $80 ore shoot, at 275 feet west of the shaft, the hanging wall is an altered pyritic bluish-green andesite, similar to that described on the fourth level, but it is extremely dense, and the pyrites are similarly so fine as to be almost invisible. The foot wall at this locality seems to be the altered red and brown stained lithoidal rhyolite.

At 400 feet west of the shaft the values cease, and the vein soon pinches down to 3 or 4 feet in width and presently disappears, the two fissure walls lying together for a distance of 90 feet. The rock in the hanging wall, notably at 400 feet west of the shaft, is the shattered chloritic andesite and contains veinlets of adularia and quartz, while the lithoidal rhyolite continues in the foot wall, and at 450 feet west of the shaft the two walls are separated by a 1-inch seam or dike parting of the rhyolite.

At about 500 feet west of the shaft ore again comes in and continues for 162 feet beneath the silicified rock and quartz butte croppings to a point beneath the Tozier shaft or extension winze. At 660 feet west of the shaft the vein rapidly splits up or gives way to country rock and continues barren, except for a small stringer. The vein matter and the walls are loose and barren and continue so to the end of the drift 300 feet distant at a point within 200 feet of the west Gold Road mine. Where the vein breaks up at 660 feet west of the shaft the hanging-wall rock is the andesite and the foot wall the rhyolite whose normal position is regarded as the hanging wall.

East of the main shaft the vein is 12 feet in width, and the rock wedge between the vein and the stringer is 10 feet thick. At 150

feet east of the shaft the stringer bears off to the south-southeast at an angle of about 40° with the vein, and vein, foot wall, and stringer are all worked for a distance of about 12 feet, beyond which the vein pinches down to 3 or 4 feet in width, with the ore running $16 to the ton. The walls are good. The hanging wall contains both the green chloritic andesite and the red rhyolite, while the foot wall consists principally of the silicified red rhyolite. Striations on the hanging wall dip 35° SE. At 200 feet east of the shaft occurs a break or faulting of the vein, the dip of the fault plane being 65° W. On looking southeast-east along the drift the vein is seen to have slid downhill about 40 feet, as shown also by surface croppings, and beyond this the vein is cut off and the drift or tunnel continues in "country rock," which is chloritic trachyte on the hanging wall and relatively fresh andesite on the foot wall.

On the 600-foot level the vein contains much more spar or calcite than on any other level and the ore shoot is reported to have an uninterrupted extent of 1,100 feet. Some sulphide ore containing pyrite, the first encountered in the mine, was found here, and it is reported to have contained higher values than the overlying oxidized ore. At the landing the foot-wall stringer described as occurring on the 500-foot level lies near the shaft. The walls are reddish oxidized andesite (?) and, as shown in the hoist station, the hanging wall is mineralized for a distance of 30 feet or more laterally from the vein. At 100 feet west of the shaft the ore consists principally of greenish quartz with adularia and calcite, and carries good values, and at 120 feet west the foot-wall stringer from the shaft, here about 20 feet wide and all good low-grade ore, comes in and joins the vein. A crosscut 30 feet in length from the hanging wall of the vein has not yet reached the foot wall of the stringer. The hanging wall of the vein here is coarse breccia, probably of andesite tuff, more or less soft, and is coated with downward-facing comb quartz and spar. Fresh striations on the hanging wall decline 55° NNW. The movement has produced 2 feet of fault breccia, which is cemented by quartz and spar. In the hanging-wall face of the crosscut the rock seems to be the lithoidal rhyolite and the rock in association with the stringer andesite. At 204 feet west of the shaft the foot-wall stringer, which from the shaft to this point is fairly good only and contains much spar, comes into the vein and greatly enriches it from this point westward, and the foot-wall rock carries some sulphides. At 312 feet west of the shaft the hanging wall is in places gash veined and partly mineralized, and the foot wall contains hard andesite breccia with some quartz-spar ore in large bunches frozen to it. Where the ore is thus frozen to the walls in the mine the wall has usually to be broken to get the ore. At 400 feet west of the shaft the vein is cut off abruptly by the same fault that cuts off the ore shoot on the 500-

foot level. Here the break is about 12 feet west of the point it occupies on the 500-foot level and the hanging wall is cross sheeted into slices from 4 inches to 1 foot in thickness, while on the 500-foot level it is smooth and the foot wall is brecciated rhyolite. Farther west the vein is represented by a barren stringer 1 foot or more thick, which seems to extend for a distance of 40 feet to a point where good stoping ore, consisting mostly of quartz with some spar and some brecciated angular fragments of country-rock andesite, comes in and continues westward for a distance of 162 feet. The maximum thickness of this 162-foot ore shoot is 16 feet, and here it carries the richest ore.

At 500 feet west of the shaft a 4-foot spur, vein, or stringer goes off at a short angle from the vein to the southeast-east in the foot wall. It dips about parallel with the vein and does not seem to affect its ore values. It has been mined for a distance of 15 feet. The face of the drift in it shows a gold-bearing black band, several inches in width, containing principally oxide of manganese. At 600 feet west of the shaft, in the face of the drift and beyond, the vein has pinched to a width of 2 feet and seems to narrow with depth.

East of the shaft the country rock is the reddish silicified andesite. The vein is split or composite and consists of alternating bands of stringers of quartz, calcite, and country rock. At 80 feet east of the shaft the vein pinches and almost entirely gives way to country rock. There is no sign of a fault, but the walls are rough and some barren vein material extends on to the face of the drift. At 140 feet east of shaft, where the vein is 4 feet wide, occurs the cross fault of the fifth level, which cuts the vein nearly at right angles. The country rock is a greenish-gray epidotized porphyritic andesite.

At the time of visit the 700-foot level was just being opened. About 35 feet northeast of the shaft a stringer or vein 2½ feet in width was cut, whose position, attitude, and other characteristics correspond to those of the Gold Road vein. Numerous small stringers and veinlets lie on either side, and the rock, which from the shaft to the face of the crosscut is in general massive, is here for a width of 6 or 7 feet on either side of the vein sheeted into slices down to 3 or 4 inches in width. Just above this locality, on the 600-foot level, the vein is reported to have split into three parts. The vein is frozen to the walls and composed of greenish quartz and calcite; it is imperfectly banded, brecciated, and in part iron stained and oxidized. It contains, according to assay returns, $11 in gold to the ton. In contact with the vein is greenish, dense, very hard andesitic rock, traversed by numerous veinlets of chalcedonic quartz and adularia. On the foot wall the rock is less dense and looks like an agglomerate.

Near the face of the crosscut occurs a 2½ to 3 inch stringer, which consists of nearly all quartz with a little associated dark calcite and is said to contain about $16 in gold to the ton. Its strike is more

northerly than that of the vein, with which it makes an angle of about 30° and which it probably joins a short distance to the east. The face of the crosscut is a medium to coarse grained dull-greenish propylitic trachyte. (See analysis, p. 39.) It is a totally different rock from the green chloritic andesite described on pages 34–37, which occurs elsewhere in the mine. It is intruded by a fine-grained reddish and greenish rock, probably andesite. In the landing and crosscut as a whole, however, particularly in the southern half, the prevailing rock is the massive dark sulphide-bearing green chloritic andesite, which seems to be the principal country rock and apparently indicates that the bottom of the mine, so far as the country rock is concerned, has practically reached the sulphide zone, although no sulphides have as yet appeared in the vein. Late in February, 1907, this level was reported to be showing good ore bodies, the values of which are said to be comparable to those on the sixth level.

The Tozier shaft, also called the west winze, is 600 feet west of the main shaft and starts on lower ground; it was being sunk at the time of visit and was then 90 feet in depth, having penetrated nearly to the projection of the 200-foot level in the main part of the mine. It here shows a good-looking 5-foot vein of ore said to run about $11 to the ton. The company expects, in case the ore body extends to the west, to connect its workings with the West Gold Road mine, 400 feet distant.

BILLY BRYAN MINE.

Location and development.—The Billy Bryan mine (see Pl. X) is located nearly half a mile southeast of the Gold Road mine, on the Billy Bryan claim in Gold Road Gulch, on the Gold Road vein, at about 3,300 feet elevation. Before it was acquired by the Gold Road Company, which now owns it, the mine was worked to a considerable extent by lessees. As shown in the section of underground workings, it is developed by about 2,500 feet of work, consisting principally of an adit drift 1,200 feet long and three shafts from 100 to 150 feet in depth. The adit drift, commonly known as the "Line Road tunnel," starts on the Line Road claim, lying between the Gold Road and Billy Bryan claims at about 3,200 feet elevation and extends to the southeast, where its face on the eastern part of the Billy Bryan claim lies about 250 feet below the surface. Beyond this point important surface workings extend interruptedly nearly to the east end of the Railroad claim, which joins the Billy Bryan on the east.

Geology.—The geology is essentially similar to that of the Gold Road mine. The country rock is the group of undifferentiated volcanic rocks, whose variations and phases are well shown in the large dump at the mouth of the drift. The principal rock corresponds more closely to trachyte than to dacite or rhyolite, and is in general con-

siderably altered. The rocks are locally faulted and are intruded by rhyolite and dikes of the young reddish-brown andesite.

The croppings of the Gold Road vein at the Billy Bryan mine are prominent and wall-like, but they probably do not represent the whole of the deposit. It is believed that the vein is split throughout the Line Road claim, the beginning of the split being at the mouth of the main drift. A stringer diverges here to the left, or north, and within a short distance enlarges to a side vein of fairly well-banded good-looking quartz 3 to 4 feet in width and carrying moderate values. After nearly paralleling the vein for 1,200 feet at a distance of about 100 feet, this stringer reunites with the vein near the east end of the deep works on the Billy Bryan claim, where good ore occurs at the junction and beyond. The area contained between the two veins is traversed by numerous parallel quartz stringers and veinlets. Just beyond the point of junction a similar side vein, not shown on the surface, is said to have been encountered by a deep crosscut 80 feet north of the vein.

The vein on the Billy Bryan claim varies from 1 to 20 feet in width and dips, in general, steeply to the southwest instead of normally to the northeast. It consists mostly of spar or calcite, which contains bands of greenish quartz; in places, however, quartz forms the principal part of the vein. Farther southeast, beyond the limits of the Billy Bryan claim, and in fact to the end of the Railroad claim, quartz prevails and carries good values. The quartz is greenish with glassy luster and locally is very brittle and finely ribboned or banded, wavy, and crenulated, its structure resembling the fine flow structure of certain lavas.

In the Billy Bryan shaft the ore for the first 25 feet in depth is reported to be of small value. From 25 to 80 feet the values were good, but below 80 feet they are said to decrease. On the Line Road and Billy Bryan claims the gold occurs chiefly along the contact of the red jasper or jasperoid brown quartz and white or green quartz and along the bands in the glassy quartz that may be present. In the eastern part of the Line Road claim and in a considerable portion of the Billy Bryan and Railroad claims the vein has produced very rich shipping ore in the surface workings, and it is under these workings, notably on the Billy Bryan and Railroad claims, that the Gold Road Company expects favorable results. Advices from the mine in June, 1908, stated that the company was sinking two shafts on the Billy Bryan claim to connect by drift with the Gold Road shaft and had encountered good ore as deep as the shafts extended.

In its extension eastward across the Last Chance claim and the crest of the range the vein contains some good croppings and openings, but it is split by horses at one or two points and locally narrows to unworkable dimensions. It may, however, be found to widen in depth as it descends in horizon in the Gold Road and Billy Bryan mines.

WEST GOLD ROAD MINE.

The West Gold Road mine is located in Gold Road Gulch, about 600 feet west of the main shaft of the Gold Road mine and on the projected course of the Gold Road vein; it has an elevation of about 2,800 feet, or 100 feet below the collar of the Gold Road shaft. Work was begun on the West Gold Road property in 1905. The property is owned by the West Gold Road Mining Company, with headquarters at San Francisco. The mine is developed principally by a shaft 455

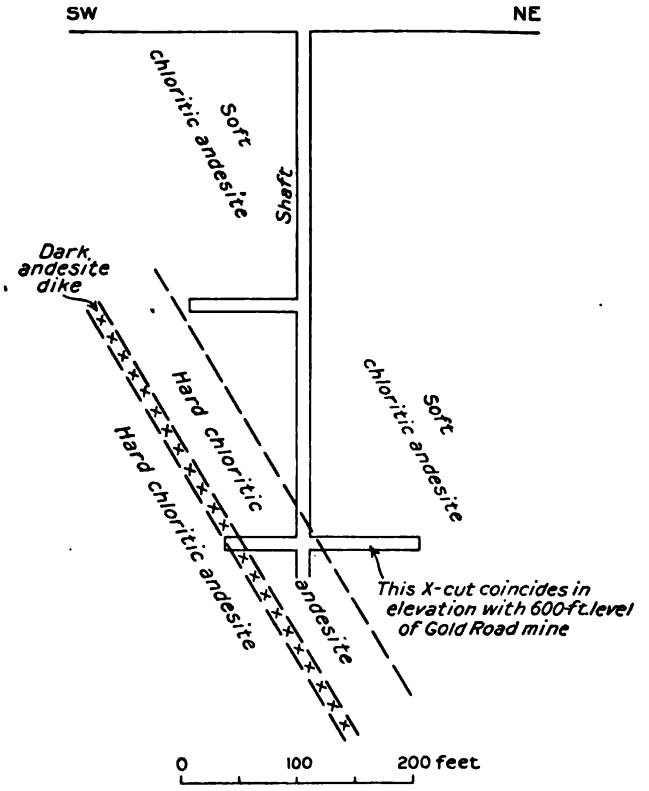


FIGURE 29.—Cross section of workings of West Gold Road mine.

feet deep and about 200 feet of crosscuts (fig. 29). On the 240-foot level the crosscut extends 45 feet to the southwest and on the 440-foot level, which corresponds to the 600-foot level of the Gold Road mine, the crosscut is driven 65 feet to the southwest and 100 feet to the northeast.

The country rock, and about the only rock encountered in the mine, is the green chloritic andesite. It is pyritic and contains quartz and chalcedony-pyrite veinlets. In the lower, southwestern part of

the mine the rock is less altered and is cut by a dike of younger dark andesite about 7 feet in width, dipping steeply to the northeast, nearly parallel with the vein, and encountered principally at the end of the crosscut to the southwest on the lower level.

The developments above cited were made in the hope of finding workable ore on the northwestern extension of the Gold Road vein, but the only deposit encountered is a ledge or vein of mixed bluish and drusy quartz and altered, slightly pyritiferous rock. This vein occurs in the crosscut to the southwest on the 240-foot level and probably represents the Gold Road vein; it is 5 feet wide and dips 86° NE. It is said to average about $2 in gold to the ton and the deposit is not workable at this point.

PASADENA MINE.

Location and history.—The Pasadena mine (see Pl. X) is about 1½ miles west of Gold Road, on open, gently sloping ground that drains northward into Silver Creek, at about 2,550 feet elevation. The mine was located about 1900 and had been working about two years at the time of visit. It is still in the development stage. The property comprises seven mineral claims, five being continuous along the vein and two being side claims. It is owned by the Pasadena Consolidated Mines Company, with headquarters at Pasadena, Cal.

Developments.—The mine is developed mainly on the Rhine Gold claim, principally by a shaft 318 feet deep, three levels containing about 100 feet of drifts and crosscuts, and by surface openings. A small shaft 55 feet deep is located 820 feet south of the main shaft.

The principal equipments are a gasoline hoist and a 2-stamp prospecting mill for testing the ore bodies in development work. The water supply is piped by gravity from Cottonwood Springs, 3 miles to the northeast, at Battle Mountain.

Geology.—The country rock is the green chloritic andesite, which here, particularly in the side of the gulch to the west of the mine and in the dump, is shown to vary in a very short distance, even in a hand specimen, from the soft, altered greenish chloritic phase to the fresh, hard black rock. A fuller description of the rock appears on pages 34–37. The rock shows characteristic propylitic alteration along the vein. Angular blocks of the rock a foot in diameter and many smaller fragments are inclosed in the vein.

The rock is intruded by dikes and masses of rhyolite and by dikes of a basic but quartz-bearing greenstone porphyry. One of these dikes, of greenish color, 20 feet in width, and trending east and west, is cut by the vein about 3,000 feet south of the hoist. The dike is here prominently cross sheeted parallel with the vein.

Veins and ore.—The Pasadena vein or lode varies from 10 to 140 feet in width. It strikes about N. 10° W. and dips about 70° W.

It is reported to extend throughout the length of 19 claims and to be continuous with the vein of the Tom Reed or Blue Ridge mine on the southeast; if this is correct it has a length of several miles.

To the north the vein does not seem to retain its development more than a few hundred yards beyond the mine and hoist. To the northwest, however, where the gulch from the south enters Pasadena Wash, a vein of calcite 2½ feet wide and striking northward is prospected, but is not proved to be a part of the Pasadena vein, which it may, however, join farther north.

The croppings consist essentially of reefs of iron and manganese stained quartz and some gray calcite. They show polished faces with horizontal striation. In the Pasadena mine the walls are reported to be firm, well defined, and regular and to stand well.

The vein consists essentially of calcite and quartz, the quartz increasing in amount with depth. Some of it is of the greenish Gold Road type and this carries the best values. The calcite or spar portion of the ore is said to contain its best gold values in the minute black specks and dendritic bodies of iron and manganese, which it carries widely disseminated.

The average values of the ore are reported to be about $10.50 a ton and the ore is said to be suitable for the cyanide process. In the main shaft, which is on the west spur of the vein, the ore is said to average $11.20 in gold to the ton from the surface down, the ore shoot varying from 4 to 10 feet in width. At a smaller shaft 55 feet deep mill runs of ore are reported to have given results as follows: Surface, $5.56; at depth of 25 feet, $12.45; and at 55 feet, $24 in gold to the ton. The ore at these depths is reported to extend the entire width of the shaft, with only one wall in sight.

MOSS BACK MINE.

Location and history.—The Moss Back mine is situated 3 miles by trail northwest of Gold Road, in open country near the foot of the range, at about 2,400 feet elevation. It is near the upper edge of a bluff about 80 feet high overlooking a wash on the northeast. The property comprises three claims. It is reached by wagon from Gold Road in a distance of 7 or 8 miles by descending Silver Creek nearly to the Moss mine road forks.

The deposit was first located about 1863 by the Barry Mining Company as the Blanco ledge, so-called from the whiteness of its croppings and ore. It was relocated in 1864 and thereafter abandoned and finally it was again relocated in 1901 by Charles H. Burlock and wife, of San Diego, Cal., who still own a four-fifths interest in it, the remaining fifth being owned by the Moss Back Mining Company, of Los Angeles.

There has been no production, but about 900 tons of what is said to be good milling ore lies on the dump.

Development.—The mine is developed principally by a main shaft, drifts, and crosscuts to a depth of 330 feet. The workings also include a crosscut tunnel 150 feet in length on the southwest. The mine is said to produce a plentiful supply of water for ordinary milling purposes. The water rises within 170 feet of the surface. The mine is now dismantled of its hoist and surface equipments and the ladders have been drawn from the shaft. Besides the water produced by the mine a never-failing source of supply is a constant spring located at the foot of the range about a mile northwest of the mine and about 400 feet above it, with which there are pipe-line connections.

Geology.—The Moss Back deposit is geologically and mineralogically very similar to that of the Pasadena mine. The country rock is the green chloritic andesite; it is locally pyritic and is intruded by rhyolite dikes and masses and by fresh black basalt or basaltic andesite. The structure or sheeting trends about N. 80° E.

The rhyolite is also in part mineralized and is reported to assay from $2 to $3 a ton all over the surface; it contains veins or reefs of silicified rock, and is cut by diabasic basalt dikes. In the small hill east of the mine it contains a 1 to 2 inch rich gold-bearing stringer with much hematite.

Veins and ore.—The Moss Back vein or lode dips about 80° SW. and has a known extent of nearly half a mile; the width at the surface is at least 23 feet, and it is said to widen to 40 feet in the bottom of the mine. The vein consists essentially of a mixture of gold-bearing, medium to coarsely crystalline calcite, with a small percentage of fine-grained silica or quartz and probably adularia, which has seemingly replaced calcite. It also contains a considerable amount of the greenish mineralized country-rock andesite, which occurs in streaks or small bodies and carries low-grade values.

The croppings are more or less silicified portions of the vein above described, for the most part stained by iron and manganese oxides, and contain in places masses or clusters of quartz blades representing the replacement of calcite by the quartz along its crystal faces and cleavage planes. There is but a small amount of gouge, but the wall rock next the vein is usuall sheared, silicified, and veined by quartz or calcite.

The principal portion of the vein or main ore shoot, the part best defined at the surface, has a width of 12 to 15 feet and contains from 4 to 6 inches of gouge material consisting of sheared and crushed rock, calcite, and quartz on its foot-wall side.

The ore almost everywhere contains disseminated minute blackish specks of hematite, and these, particularly in the spar, are reported to carry the gold in very finely divided particles. The values rise

with increase in the amount of silica in the spar, the best ore being in association with the silica. Some small pockets of yellowish-brown "sugar quartz," which consists principally of colored spar, with an admixture of silica and limonite, are said to have contained up to $2,000 in gold to the ton.

A 17-foot crosscut from the main shaft to the southwest at a depth of 200 feet below the surface, which has not yet reached the hanging wall, is said to show good ore throughout its extent, running from $6 to $9 to the ton. In the shallow workings on the southeast a 10-foot width of the vein is reported to average $31 in gold to the ton.

MOSS MINE.

Location and history.—The Moss mine is about 4 miles northwest of Gold Road and 2¼ miles west of the Moss Back mine, to the north of Silver Creek. It lies in a well-mineralized area on the southeast slope of a group of outlying hills, the Moss Hills, which trend west to a point about 1½ miles beyond the mine. This mine, the original discovery in the country here discussed, was located in 1863 or 1864 by John Moss, who found much free visible gold exposed in the croppings about where the shaft is now sunk. On this spot, from a hole about 10 feet in diameter and depth, he took out $240,000 in gold, all of which he immediately spent in development work, much of which was ill advised. Moss died later in poverty.

The rich ore was contained in reddish-brown hematite or iron-stained quartz croppings, which Silliman[a] aptly describes as having the appearance of sulphide-bearing quartz that had been roasted. Much of it was covered with flakes, incrustations, and beads of gold from the size of shot or pea to that of a hazelnut. Two tons of ore taken from the outcrop of the vein is said to have netted $114,000 in San Francisco, and the exhibition of this rich ore led many men to brave the dangers of the desert and the Indians to reach the district.

The mine was worked principally in pioneer times, at first by the Moss Brothers. After the rich find a 10-stamp mill was built on Silver Creek just below the Holmes camp, where some of the ore may still be seen. Dahlgreen Black is said to have enlisted eastern capital and operated the mine after the Moss Brothers. The property, including several patented claims, is now owned by the Gold Giant Mining and Milling Company, with headquarters at Los Angeles. Some development work was done on the property in 1906. The total production is $500,000.

Developments.—The developments consist principally of a 230-foot double-compartment shaft and about 600 feet of tunnels and crosscuts. The shaft starts on the hanging-wall side of the vein

[a] Silliman, Benjamin, jr., Am. Jour. Sci., 2d ser., vol. 41, 1866, pp. 289–308.

and now contains some water. Much of the horizontal underground work is 8 by 10 feet or more in cross section and was done in the pioneer black-powder days at great cost.

The tunnel starts in a gulch about 100 feet south and 60 feet below the collar of the shaft, whence it extends diagonally to the northeast for a distance of about 250 feet, following a stringer in part nearly to the vein. It then parallels the vein westward as far as the shaft, with which it connects by a crosscut. Other crosscuts open the vein at intervals and extend into the foot wall on the north. Several shorter crosscuts also extend to the south on good-looking spur veins or stringers, but in no case more than about 30 feet, which seems to indicate that the values were too low to pay.

The principal equipments are a good gasoline hoist and a small mill at Hardyville, near the mouth of Silver Creek, on Colorado River, 7 miles distant.

Geology.—The country rock is a quartz syenite porphyry phase of the granite porphyry and micropegmatite described on page 30, but contains more hornblende and biotite. It forms a considerable part of the Moss Hills and underlies the younger volcanic rocks in the vicinity. Northward it extends for a distance of half a mile or more to a point about one-fourth of a mile beyond the Moss mine saddle and southward nearly to Silver Creek and the Holmes camp, probably connecting locally with the same rock in the Hardy Mountains. It weathers reddish brown.

Veins and ore.—The Moss vein as seen underground has a width of about 22 feet and a known extent of more than half a mile and a reported extent of about 4 miles, being held by some to connect with the Moss Back vein. It dips steeply to the south and is associated with considerable fault breccia on its foot-wall side. Both sides of the vein are frozen to the walls, and in consequence of this the walls are torn and ragged where the vein has been mined.

The croppings, which in large part are prominent and of the Gold Road type, consist principally of a surficially iron-stained mixture of quartz and crystalline calcite and probably adularia and silicified rock, which in part is porous or honeycombed and is cut by a cross sheeting or slickensiding.

In the underground and less-oxidized vein the quartz and calcite are present in about equal amount and the quartz seems to have replaced calcite, both minerals being usually fine grained and very intimately intermixed or intergrown. The quartz is mainly of a greenish hue, like that of the Gold Road vein, but a considerable portion is also pale rose-red, from which the vein has commonly come to be known as the rose-quartz vein.

Under the microscope a section of the ore shows coarse granular quartz, with coarse calcite grains, also acicular calcite in triangular

pattern and intervening finer-grained quartz; the quartz appears divided in sectors through the distribution of radial inclusions, probably mostly fluid. No adularia was seen in the section, but it is probably present in the ore.

East of the mine, at the wagon-road gap, where a good surface opening has lately been made, the vein has narrowed to a few feet in width, and in the most easterly crosscut on the level of the tunnel in the mine, about 100 feet east of the shaft, it is split into several parts or stringers by horses and inclusions of the country rock.

Nearly the whole production seems to have been obtained from very rich pockets or concentrates in the croppings and highly oxidized ore near the surface, for deeper work shows the deposit to consist principally of a large body of low-grade ore, much of it averaging about $4 in gold to the ton. Several tons of the ore are reported to have averaged $6,800; two tons $42,500 each in San Francisco; and a lot of about 100 tons, which was treated at the small mill at Hardyville, about $42 a ton.

Lying near the Moss vein on either side are one or more small veins or ledges, on which assessment work is kept up. The principal one on the north is about parallel with and 500 feet distant from the Moss vein, and contains much fluorspar.

RATTAN MINE.

The Rattan mine is 4 miles northwest of Gold Road and about one-fifth of a mile south of the Moss mine, in the south base of the Moss Hills. The property comprises two claims, the Rattan and Ruth, which have been patented since 1894, but it has not been worked for some time. It is owned by the Rattan Mining Company of Kingman.

The mine is developed principally by a 200-foot shaft, about 200 feet of drift, and considerable stoping on the 100-foot level. The principal equipments are a gasoline hoist and a 10-stamp mill; the latter being located 7 miles distant, on Colorado River at Hardyville. Several hundred tons of the ore were treated in this mill.

The country rock is a quartz syenite porphyry phase of the granite porphyry and micropegmatite, the same as at the Moss mine, except that here it is finer grained and contains considerable iron pyrite. It exhibits two structures which are variable, one trends N. 15° E. with dips steeply to the east and the other trends about east and west with dips steeply to the north.

The Rattan vein dips about 80° N. Openings on it extend interruptedly for about three-fourths of a mile to the east. So far as seen at the surface the vein is 2 or 3 feet wide, and the ore body is said to be up to 2 feet in width. It consists principally of calcite or spar, quartz, and crushed rock, and contains green fluorspar.

The vein in the bottom of the mine is said to be about a foot in width and to contain a shoot of $300 ore 1 inch wide. The ore differs from the Moss ore principally in containing pyrites. Some good ore has been shipped and a considerable amount has been milled. Several hundred tons were treated in the company's mill at Hardyville, but owing to its sulphide content a high extraction was not obtained.

GOLDEN STAR GROUP.

The Golden Star group of mines comprises seven or eight properties, mainly in the prospect stage, situated in the northwest corner of the district about 2 miles northwest of the Moss mine. They extend from the north slope of the Moss Hills northward mostly on open ground to Cottonwood Wash, a distance of about 2 miles.

The camp is located in the northern part of the area at about 2,200 feet elevation, just south of Cottonwood Wash and about 140 feet above it, near the point where the wash passes from open country into a canyon. It is reached by wagon road leading from the Moss mine northward, thence westward down Cottonwood Wash.

The group is owned by the Golden Star Mining and Milling Company, of Pasadena, Cal. The principal openings of the group are on the Golden Star, West Point, American Boy, and Red Bluff claims.

West Point prospect.—The West Point prospect is located in the lower west slope of the Moss Hills, on the West Point claim, about half a mile south and 100 feet above the camp, in gray andesite, which here contains considerable breccia. The vein is about 3½ feet in width. It strikes N. 65° W. and dips about 80° NE. It has very much the appearance of a finely sheeted or cleaved dike, subsequently silicified, and is said to contain the highest-grade ore in the camp. The ore is of the quartz-adularia type and its values are in gold. A microscopic section shows it to consist of quartz of variable grain, limonite, and a small amount of adularia.

American Boy mine.—The American Boy mine is about a mile south of the camp and 800 feet above it, in the upper north slope of the Moss Hills. It is developed by a 110-foot crosscut tunnel, 200 feet of drift, and a 60-foot shaft sunk to a level with the drift and tunnel.

The country rock is a medium-grained bluish-gray rock, which seems to be an andesite and is locally pyritic. It is cut by a cross sheeting that dips steeply north and a jointing that trends north-northwest. An east-west dike of coarse, porphyritic andesite crosses the mouth of the tunnel.

The vein dips steeply to the northeast. It varies from 6 inches to 2 feet in width and contains chiefly impure gray and dark, coarsely crystalline calcite with local bodies of dense greenish quartz about an inch in maximum diameter. It is tightly frozen to both walls. The

croppings are silicified country rock and spar, and some of the surface ore is said to have averaged about $100 in gold to the ton.

Golden Star mine.—The Golden Star mine is about a mile southeast of the camp, in the lower north slope of the hills, in a gulch that trends to the northwest (Pl. XII, *A*). The country rock is dark-gray pyritic andesite, which near by rests upon an older coarsely porphyritic green rock and locally upon the pre-Cambrian pegmatitic granite which here forms the core of the hills. The vein is composed of calcite and quartz, the croppings of which are stained by iron and manganese oxide. It varies from 1 to 14 feet in width, dips 65° to 70° N., has a known extent of about a mile, and is cut by the Meals Ledge (see p. 176) on the east. On the hill slope west of the mine the vein is associated with thin, dense green porphyry dikes which parallel it.

The mine is developed by a 90-foot shaft. The vein here contains about 3 feet of good-looking calcite or spar, but is of too low grade to be workable.

Red Bluff prospect.—The Red Bluff prospect is just north of the camp, on the sides of a long, narrow north-south fault block, where it is crossed by Cottonwood Canyon, whose floor here lies about 140 feet below the neighboring surface. The fault block is about 50 feet wide. It dips 70° E. and extends into the Moss Hills, a distance of more than a mile.

The country rock is a gray andesite, which rests upon the pre-Cambrian coarse granite or pegmatite that floors the canyon. These rocks are intruded by a granite porphyry dike 40 feet wide at right angles to the trend of the fault block. After the intrusion of the granite porphyry the dike was cross faulted, and the country rock on the west or foot-wall side of the fault block, including the dike, was carried by lateral throw about 150 feet to the south, to a point about west of the camp. The amount of movement along the fault plane of the fault block has been considerable and has produced from 1 to 14 feet of fault breccia, crushed rock gouge, etc., and here mineralization has taken place.

The best values occur in red, oxidized streaks, principally on the hanging wall, but also on the foot-wall fault plane, and are usually associated with or near by the granite porphyry.

The granite porphyry is a pink or reddish rock with a medium or fine grained groundmass containing phenocrysts of quartz. It contains no ferromagnesian silicates, and under the microscope shows some silicification and secondary growth of adularia.

The property is developed principally by a 45-foot drift and a 50-foot crosscut. The drift, starting near the bottom of the canyon, extends to the south on the hanging-wall fault plane, principally in fault breccia and pre-Cambrian granite, with granite porphyry on

A. GOLDEN STAR MINE AND FAULT BLOCK, LOOKING SOUTH.

B. GOLD ROAD VEIN AT EAST OF LINE ROAD CLAIM, LOOKING NORTHWEST.

its hanging-wall side. From its face the crosscut has been driven through the fault block to the foot wall, without encountering much ore. This deposit appears to warrant further prospecting.

VENTURE PROSPECTS.

The Venture prospects, owned by Thomas Patterson, of Gold Road, are situated in open, gulch-scored ground, just north of Cottonwood Wash. The country rock is a gray medium to fine grained fresh biotite andesite closely related to that in the Moss Hills on the south; on the north are old greenstone tuffs in which the sheeting dips steeply to the south-southwest.

The principal exposure occurs on Venture claim No. 2. Here the vein or ledge containing the deposits is vertical or dips steeply to the north-northeast, and, where open to the depth of about 8 feet, presents the following section, beginning on the hanging-wall side:

Section of vein on Venture claim No. 2.

	Ft.	in.
Country rock, somewhat crushed along face of hanging wall.		
Chiefly impure calcite with but little quartz, stained and mottled orange and greenish (principal part of the vein)	1	6
Yellowish-green talcose gouge		2½
Brecciated greenish rock spar and gouge material	1	
Foot wall, containing 1 to 3 feet of crushed country rock.		

The values, said to be fair, are contained principally in the firmest portion of the vein and in the heavy red or red-brown iron-stained rock along its sides. The croppings are mostly weathered calcite, some of which, as well as the surface ore, yield $6 in gold to the ton.

MEALS LEDGE.

The Meals ledge, a large gold-bearing calcite vein or lode of low-grade ore, is located east of the Golden Star group. With certain interruptions, it extends from the saddle in the Moss Hills near the Moss mine northward for a distance of nearly 2 miles, its general strike being N. 30° W. It is best developed in the open mesa country between Cottonwood Wash and the Moss Hills, where the principal locations are owned by W. H. Meals, of Gold Road. Here it varies from 10 to 60 feet in width, with an average width of perhaps about 40 feet, and dips in general about 65° ENE. It is composed principally of coarsely crystalline calcite, with usually a small amount of quartz, and locally contains, particularly in the croppings, much angular crushed andesite, quartz porphyry, and other rock.

The country rock forming the hanging wall of the vein for a considerable distance south of Cottonwood Wash is greenstone (altered andesite?) containing bowldery inclusions of the pre-Cambrian gran-

by the vein may formerly have been occupied by a dike of the micropegmatite, which the vein later replaced.

Beside the main vein above described there are also several smaller veins. In the middle east slope of the hill in which the mine is located the vein near its east end is intersected by a smaller north-south vein. This cross vein varies from 6 inches to about 3 feet in width and is younger than the main vein, which it cuts. It is otherwise similar to the main vein and has received considerable development in the mine, mostly to the north of the main vein, and has contributed materially to the production.

Also paralleling the Hardy vein and situated about 450 feet distant from it on the north is a small vein or stringer known as the McCullough ledge. It lies in the granite porphyry and micropegmatite, stands about vertical, and extends from Hardy Wash westward to a point beyond the Homestake mine, a distance of about a mile. It is prospected at several points and is said to carry good values in gold and silver.

The ore of the Miller mine contains chiefly gold, but carries also considerable silver,—more silver, it is said, than any other ore in the district or southern part of the Black Mountains. The ore is reported to average about $6 a ton, but some very rich ore is also present.

JACK POT MINE.

The Jack Pot mine, owned by Maj. R. J. Holmes, of Gold Road, is about one-fourth of a mile west of the Miller mine, in the upper north slope of the mountain, at about 2,500 feet elevation. It is on the Hardy vein and in country rock of granite porphyry and micropegmatite. It is developed principally by a 160-foot shaft and drifts and is equipped with an 8-horsepower gasoline hoist.

HOMESTAKE MINE.

The Homestake mine, also owned by Maj. R. J. Holmes, is nearly a mile west of the Miller mine, in the upper north slope of the mountains, at about 2,450 feet elevation. It is on the Hardy vein in the granite porphyry and micropegmatite. It was formerly worked by Col. Thomas Ewing and is now bonded to the Gold Road Company. It is developed principally by drifts and shafts, the drift to the east being about 240 feet in extent, and is equipped with an 8-horsepower gasoline hoist. The vein varies from 2 to 20 feet in width, looks well, and is said to carry good values.

NAVY GROUP MINE.

The Navy Group mine (see Pl. X) is about 1½ miles west of the Miller mine, on the east slope of a north spur of the Hardy Moun-

tains, at about 2,300 feet elevation. This also is on the Hardy vein in the granite porphyry and micropegmatite.

It was located by R. E. Zuver, of Gold Road, by whom and his associate, Maj. R. J. Holmes, it was formerly owned. It is now owned by the Navy Group Mining Company, of Los Angeles. The croppings all the way up the mountain slope, several hundred feet in extent, are strong and are reported to continue so for a mile or more westward to the locality where the mountains fall off into the mesa country on the west.

The mine is developed principally by an adit drift 900 feet in length trending N. 82° W. At 500 feet in from the mouth of the drift the vein is cut off by a north-northwest fault, which should be worked out with care before deep and expensive workings are undertaken. Some seemingly useless work has been done, including 400 feet of drifting, on the projected course of the vein beyond the fault.

The principal part of the vein is from 2 to 4 feet in width and consists principally of quartz with bunches of white and gray crystalline calcite and green and red fluorspar. The ore contains principally gold with a very little silver. It is reported to range in value from $8 to $30 a ton, the best grade being associated with iron-stained quartz.

GADDIS-PERRY AND ANGLE LODES.

From Hardy Camp and the mouth of Hardy Wash on Silver Creek just north of the Miller mine a large dike or belt of micropegmatite, about one-tenth of a mile in width, described under the Miller mine, extends N. 75° W. about parallel with the Hardy vein for a reported distance of 3 miles. It seems to be intruded between volcanic greenstone agglomerate on the north and the granite porphyry and micropegmatite of the Hardy Mountains on the south. The contacts on both sides are zones of mineralization containing lodes dipping about 70° N.

The south contact zone is here called the Gaddis-Perry ledge, from the principal prospect on it, situated at its east end, and the north contact the Angle ledge, from its principal opening. The croppings of the ledges are iron and manganese stained quartz and silicified micropegmatite. They are in part porous and honeycombed, and both the croppings and the subsurface portion of the ledges carry good gold values.

The Gaddis-Perry ledge is simply a zone of quartz and silicified rock, principally micropegmatite, from 60 to 80 feet in width, with granite porphyry and micropegmatite forming the foot wall and micropegmatite the hanging wall. It contains several prospects, of which the principal one is that on the east end, owned by Gaddis & Perry, of Kingman. This prospect has several openings, of which

the most extensive at the time of visit was a crosscut driven to the length of 40 feet, showing good-looking gold-bearing quartz.

The Angle ledge is similar to the Gaddis-Perry ledge and several prospects are located on it, the most important of which seems to be the one owned by Mr. Angle, of Gold Road, situated about one-fourth of a mile northwest of the Gaddis-Perry prospect. Here the ledge is about 20 feet in width and is bounded by greenstone agglomerate on the hanging wall and micropegmatite on the foot wall, from both of which it is separated by 2 or 3 inches of whitish and reddish talcose gouge. It is opened principally by a 40-foot shaft and shows some good looking quartz, said to carry fair values in gold.

That the origin of the gold in these deposits is in some way connected with the micropegmatite seems very probable. Further support of this view is found in a somewhat similar occurrence to the north of Silver Creek, in the gulch just north of Holmes Camp. Here the country rock, volcanic greenstone agglomerate, is cut by an east-west 1 to 2 foot dike of the micropegmatite, which, like the ledges just described, dips steeply to the north. This dike has been prospected to a depth of 5 or 6 feet, and is reported to contain from $1 to $18 in gold to the ton. When followed eastward for about one-eighth of a mile the dike is found to narrow to 2½ inches in width, to lose its feldspar or rock character, and to become almost pure quartz. Parallel lines resembling flow structure traceable from the feldspathic-rock phase over into the quartz-vein phase in the same fissure.

VIVIAN DISTRICT.

GENERAL DESCRIPTION.

The Vivian district lies in the southwestern part of the region and adjoins the Gold Road district on the south, extending southward with a breadth of about 4 miles to a broad east-west wash, just north of Boundary Cone, a prominent landmark rising boldly 1,500 feet above the adjacent open country on the west. This wash may here be referred to as Boundary Cone Wash. In length the district extends from the crest of the range westward for a distance of about 5 miles, to the locality where the foothills give way to the open mesa country that slopes to the Colorado. Vivian, the principal camp, situated west of the center of the district in Vivian Wash at about 2,250 feet elevation, with a population of about 50 (formerly 150), is about 3 miles southwest of Gold Road and 14 miles northeast of Needles (Pls. X and XIII, *B*). Its water supply is piped by gravity, principally from Cottonwood Springs, located at Battle Mountain, 2 miles northwest of Gold Road.

A. TOM REED (FORMERLY BLUE RID

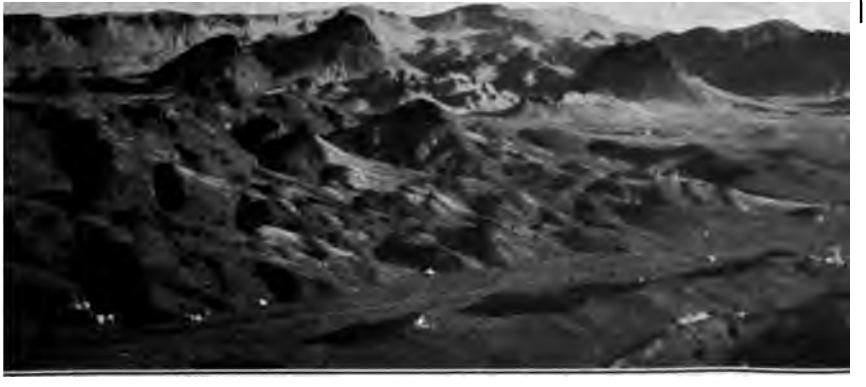
Dark volcanic rocks of range in bac

B. FOOTHILLS OF GREEN CHLORITIC

Mines of Vivian district in fo

MILL, LOOKING NORTHEAST.

by light-colored rhyolite.



)KING EAST FROM LELAND MINE.

ange in background.

The district lies in the broad belt of eroded foothills between 2,000 and 3,000 feet elevation. The topography is hilly, but usually not rough (Pl. XIII, *A*, *B*). Nearly everywhere the washes form avenues of approach by wagon. The drainage is principally to the south by Blue Ridge, German American, Vivian, and Leland washes into Boundary Cone Wash, whence it issues southwestward into the Colorado.

But little was learned concerning the history of the district, which seems principally to date from the discovery of very rich gold ore about a decade ago in the Snow Ball mine, now included in the German-American group of properties.

Geologically and mineralogically the district is essentially a southward continuation of the Gold Road district. The country rock is principally the green chloritic andesite or latite (see p. 30), which on the southwest, below Vivian, gives way to the underlying older andesite, the basal member of the volcanic series. The intrusive character of the green chloritic andesite is well shown at the head of Leland Wash, just west of the Leland mine, where dikes from 2 to 20 feet in width given off from the main mass, extend one-eighth of a mile or more westward into the older andesite. The principal effect of the intrusion here seems to be silicification and hardening of the andesite along the contact.

So far as learned the older andesite as a rule does not contain workable mineral deposits, except along lines where the latite has erupted through it. The deposits occur in fissures, which are peculiarly well developed in the chloritic andesite, but as a rule are not productive in the underlying andesite. The ability to differentiate these two formations is, therefore, of great importance to the mine operator. They are best studied by observing the rocks along their zone of contact, which is well exposed crossing the ridge just southwest of the Vivian mine, beyond which it ascends Leland Wash northward to the west of the Leland mine and the west base of Leland Monument Butte, the high, dome-shaped knob about 2,000 feet in diameter situated just west of Vivian and rising nearly 700 feet above it, on which the Leland United States mineral monument No. 1679 is located.

The deposits occur in the chloritic andesite as fissure veins or lodes from 5 to 70 feet in width, composed principally of calcite, quartz, adularia, and country-rock breccia, and in general, as in the Gold Road district, those of more nearly westerly trend are of the quartz-adularia or Gold Road vein type and seem to contain the best values. The croppings consist principally of stained quartz and calcite and silicified rock.

The principal mines in which the deposits have been worked are the Leland, German American, Tom Reed, Victor Virgin, Midnight,

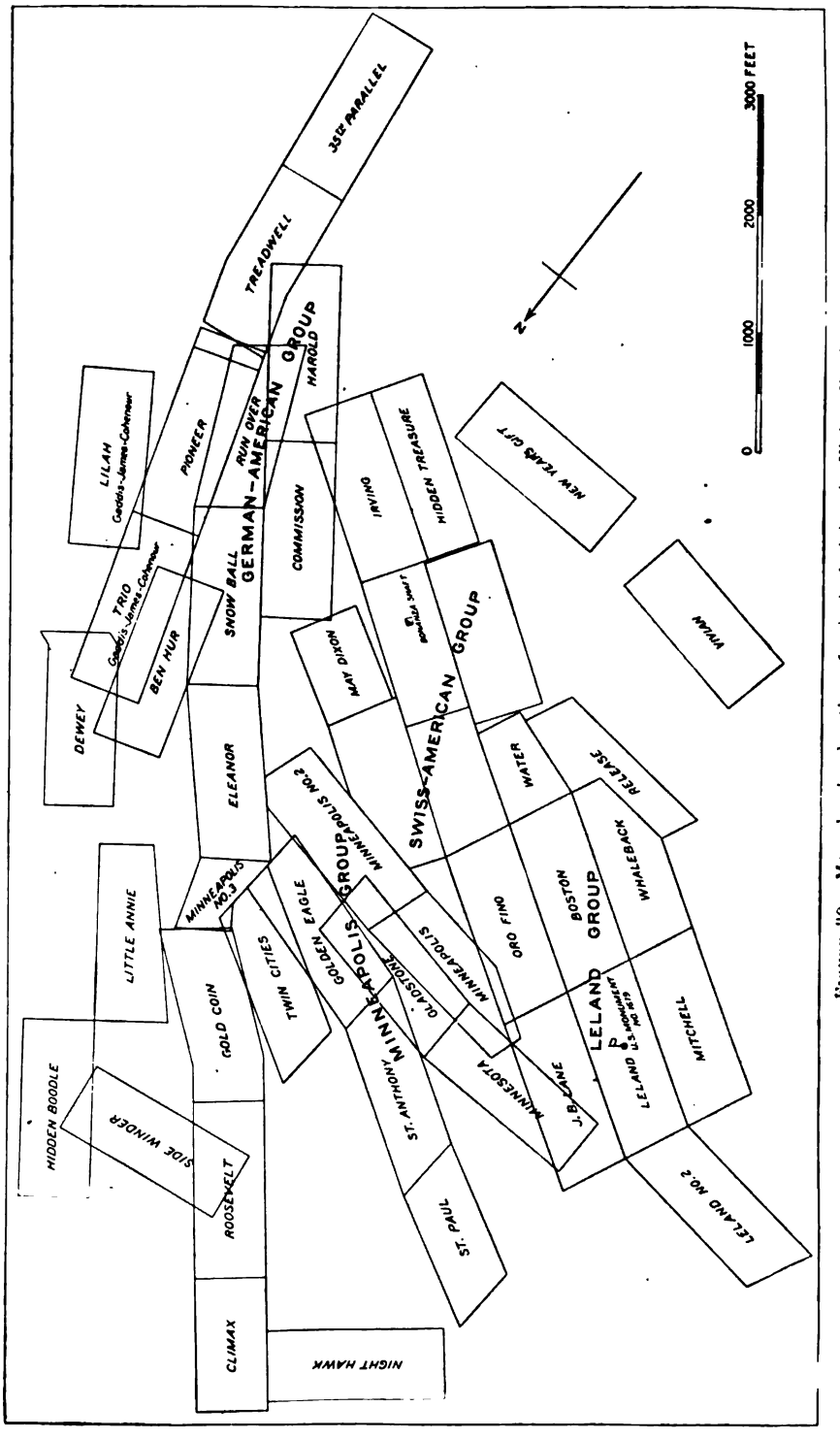


FIGURE 30.—Map showing location of principal claims in Vivian district.

A. LELAND MINE, EAST SIDE, LOOKING WEST.

B. CONTACT OF CHLORITIC ANDESITE WITH THE LIGHTER-COLORED, OLDER, UNDERLYING ANDESITE.

Ridge southwest of Vivian mine, Leland mine, and butte to the right, looking northwest.

and Vivian. Their general distribution is shown on the mine map (Pl. X), and the distribution of the most important claims on the claim plat (fig. 30), which also shows the position of the United States mineral monuments by which the properties are located.

LELAND MINE.

Location.—The Leland mine (Pls. XIII, *B;* XIV) is located just west of Vivian, on the western part of the Leland vein, in the upper part of Leland Monument Butte. The elevations vary between 2,400 and 3,000 feet.

History and developments.—The Leland property is reported to have been purchased from earlier owners in 1902 by Col. Thomas Ewing, who in 1903 sold it to the present company, the Mohave Gold Mining Company (which until January, 1907, was known as the Mount Mohave Gold Mining Company). Common reports give the price as $550,000. The property comprises a group of eight patented claims, of which the Leland and the Mitchell are the most important.

Immediately after the acquisition of the property the company began developments and operations on an unusually large scale. It installed a 12-chute ore bin at the mine at a cost of over $26,000 and a 40-stamp mill at a point which later became known as Milltown, 11 miles southeast of the mine, about 5 miles from the river, in the open, flat valley of the Colorado 6 miles from Spears Lake. It also installed a large pumping plant on the Colorado 2 miles below Needles, where, with a large Corliss engine, water was pumped through an 8-inch pipe line to the mill. In conjunction with these developments 17 miles of narrow-gage railway, the Mohave and Milltown Railroad, was built by an auxiliary company, it is said, at a cost of $268,000, from the east bank of the Colorado opposite Needles via Milltown to the mine. The freight and ore were taken across the river by ferry at Needles, where connection was made with the Santa Fe Railway.

With these equipments, installed at a cost exceeding $400,000, the company operated for a period of two years, principally during 1903 and 1904, and then closed down, mainly, it is stated, on account of failure to save the gold values in the ore at the mill. However, the company plans to resume operations in the near future, particularly in case the Midnight mine, which is now producing, continues to yield well.

The equipments above described remain at the mine. Of the 6 or 7 miles of railroad between Milltown and Needles, all but about 2 miles is said to be washed out by the flood water of the Colorado.

During the two years of operation a large amount of work was done in the mine and about 4,500 tons of ore was milled. The mine is

developed by adit drifts, tunnels, shafts, winzes, and stopes, aggregating about 3,000 feet of underground workings, distributed within a horizontal distance of about 3,500 feet and a vertical range of about 700 feet.

The most extensive part of the work is in the east side of Monument Butte, where the principal engines, ore bin, and railroad terminus are located. Here the tunnels or drifts on the lower tunnels exceed 800 and 700 feet in length and have tram connections with the ore bin. On the upper levels, toward the crest of the butte, in a vertical range of about 200 to 300 feet, extensive open-cut mining has been done and here the vein contains a width of 4 to 5 feet of very good-looking greenish quartz ore.

From the west side of the butte work on the two lower levels extends in about 600 and 500 feet, and this work is said to lack but about 125 feet to connect with that projected from the east. The portion of the vein contained between a level situated about 25 feet above the farthest 40 feet of the lower drift and the surface about 170 feet above it has been stoped out. The stoping apparently followed the richest ore only, much of which is reported to have averaged from $50 to $60 in gold to the ton.

The production of the mine was not learned, but of the 4,500 tons of ore milled a considerable amount is reported to have averaged $15 a ton and some from $50 to $60 a ton. Owing, it is said, to inefficient handling in milling a considerable amount of the gold values put through the mill was not saved.

Geology.—The country rock is the green chloritic andesite and latite, which in some parts of the mine is allied to quartz monzonite porphyry. A microscopic slide of a fresh black specimen collected in the lower east tunnel consists of a microcrystalline fine-grained groundmass of feldspar and a little quartz in which are embedded phenocrysts of orthoclase and plagioclase. In the lower part of the mine on the extreme west the chloritic andesite gives way to the underlying older andesite and is here intruded into it in the form of dikes, as has been described. A close sheeting, which seems to be the dominant structure, strikes N. 70° W. and dips 70° N. A secondary coarser sheeting or jointing strikes N. 22° E. and dips 70° E.

The black phase of the rock seems to contain considerable iron, which in some places on the upper northeast shoulder of Leland Butte renders the compass unserviceable.

Veins and ores.—The mine is located on the western part of a well-marked fissure vein, known as the Leland vein. This vein has a known extent of about a mile, strikes about N. 70° W., and dips about 75° S. At the mine it ranges from about 5 feet in width on the east to about 25 feet on the west. It is of the Gold Road type, being

composed essentially of pale-greenish quartz and microscopic adularia, locally accompanied by calcite or spar and country-rock fault breccia, and it is usually frozen to the fissure walls.

The vein is reported to contain more or less regularly throughout the mine a large amount of good ore averaging from $5 to $10 in gold to the ton. Locally the vein contains vugs lined with quartz crystals and black pulverulent oxide of manganese; many of these vugs carry much fine free gold.

The croppings of the vein consist of stained quartz and country rock containing stringers and veinlets of quartz and calcite; they are usually prominent, rising from 5 to 20 feet above the surface, and at the top of the butte they attain a width of about 40 feet, where they are locally split by a horse of the more or less silicified country rock 25 or 30 feet wide, which is traversed by stringers and veinlets of quartz and calcite and bounded on either side by 3 feet of vein quartz representing the vein, the portion on the hanging-wall side being the stronger and more persistent and direct in course. On a considerable portion of the western slope of the butte the hanging-wall side of the vein rises almost perpendicularly 60 to 80 feet above the surface and the vein is about 25 feet in width. At the west base of the butte, however, where it encounters the contact of the green chloritic andesite with the older andesite, this great vein almost abruptly ends, and it is not represented in its projected course or elsewhere in the older andesite beyond the contact. The contact, however, seems to be in part a fault contact as well as an eruptive one, as is shown where it is crossed by the lower tunnel on the west at about 100 feet in from its mouth.

East of the mine, particularly where the vein crosses the ridge on which the residence buildings stand, on the eastern part of the Boston claim, the croppings are 10 or 12 feet in width. They rise 5 or 6 feet above the surface and consist mostly of light-colored, more or less coarsely crystalline calcite or spar and quartz.

Another important vein at the Leland mine is the Mitchell vein. It is located about 400 feet south of the Leland vein, as shown in figure 30, and lies about parallel with it, but dips steeply to the north. It is opened at the south base of Leland Butte at about the same elevation as the lower drifts on the Leland vein by a 100-foot shaft and a 60-foot tunnel connected by tramway with the large ore bin. At the time of visit the shaft contained about 40 feet of water. The croppings at this point consist of a dark-stained "iron cap" of quartz, calcite, and rock several feet in thickness, resting like a detached cover on the underlying portion of the vein.

The principal opening is the shaft, but the tunnel shows some excellent examples of pseudomorphic quartz, which has replaced calcite. The vein consists of 7 feet of crushed and brecciated quartz, calcite, and country rock. The quartz is relatively pure toward the

hanging wall, but grades into a breccia of calcite, quartz, and seamed country rock. This vein, where sampled 60 feet below the surface, is reported to average about $8.50 in gold to the ton, or about the same as the Leland vein, while the rich streak of quartz on the hanging-wall side is claimed to average about $100 a ton.

Though no trace of the Leland vein occurs in the older andesite beyond the contact of the country rocks on the west, the Mitchell ledge seems to be represented there by sporadic croppings of impure dark-stained quartz or silicified rock and a little calcite, the quartz possibly being a replacement of calcite. Other croppings of a similar character occur near by, and most of them are associated with the intrusive green chloritic andesite dikes.

Although no sinking has been done to exploit the Leland ground below the lower workings above described, the ore on both the Leland and Mitchell veins, except in the extreme western part of the mine, very probably continues in depth coextensive with the green chloritic andesite to a level about 230 feet below the present lower level of the mine, or the drift commonly known as "Tunnel No. 3."

In the light of this conclusion the widely held theory that by sinking to a depth of 1,200 or 1,500 feet at a point midway between the Leland and Mitchell veins a large body of ore will be encountered at their junction should be accepted with caution, for the lower limit of the green chloritic andesite seems beyond doubt to lie at too shallow a depth for the veins to meet in this formation.

GERMAN-AMERICAN MINE.

Location.—The German-American mine (Pl. XV, *B*) is located in the southern part of the district about three-fourths of a mile east of Vivian and about 150 feet above it, in part on the German-American Wash and in part on the Vivian Wash drainage.

History.—The mine was discovered about 1896 and has been owned by the German-American Mining Company, of Los Angeles, since about 1900. The Gold Road Company, which had a bond on the property in 1902, drove the Thirty-fifth Parallel tunnel and did considerable work at the Thirty-fifth Parallel and Treadwell shafts, but most of the development was done during the years 1905 and 1906. The mine was still making weekly shipments of bullion in June, 1906, but was closed soon thereafter for lack of sufficient water to run the mill on a double shift, as it was not able to operate on a single shift with profit. The water at the time was piped from the Tom Reed mine. As the supply decreased, the mill was operated by two-hour runs only and at last shut down, but some of the property is still worked by lease. The mine produces only about 500 gallons of water a day, not nearly enough to supply the mill. For a long time before the plant was closed it was kept in operation without sinking by simply stoping from the surface and shooting the ore by gravity

to the drift and tunnel far below, as shown in the open works at the Thirty-fifth Parallel shaft.

The property comprises 12 claims, known as the Treadwell group (see fig. 30), aggregating about 200 acres, and extends through the length of about five claims nearly 1½ miles, the trend being a little west of north.

The production of the mine is about 2,700 tons of ore, which is reported and in part verified by mill records and United States Mint returns to average about $10 in gold to the ton. About 1,000 tons of the ore was produced in 1905 and 1,700 tons in 1906. A large dump at the mouth of the Thirty-fifth Parallel tunnel is reported to consist of good milling ore.

Developments.—The property is developed at various points, principally by shafts, drifts, and tunnels, to a maximum depth of about 300 feet and contains probably about 3,000 feet of underground work. The most important of the workings are at the Treadwell and Thirty-fifth Parallel shafts, which are situated about 1,200 feet apart on the vein and are connected with the mill by tramway.

From the Thirty-fifth Parallel shaft, which is 235 feet deep, and is intersected by a crosscut tunnel from the east at 170 feet below the surface, the drifts and workings extend laterally for 100 feet to the south and 120 feet to the north. From the Treadwell shaft (Pl. XV, *B*), which is 260 feet deep and sunk on the hanging-wall side of the vein, and in which the water rises to the 200-foot level, the drift on the 100-foot level extends for 160 feet to the south and 200 feet to the north; and that on the 200-foot level extends for 200 feet each way.

Pioneer shaft No. 1, the northern of the two shafts on the Pioneer claim, situated about 1,600 feet north of Treadwell shaft, is 240 feet in depth and contains several hundred feet of drifts and crosscuts on its two levels.

The principal surface equipments are a 10-stamp mill of 900-pound stamps, a cyanide plant, three steam or gasoline hoists distributed at the principal shafts, tramways, offices, and other buildings.

Geology.—The country rock is the green chloritic andesite, which in the southern part of the property, west of the vein on the foot-wall side near the tramway, is in contact with the older underlying andesite. The vein appears to lie on an eruptive fault contact of these two rocks. This older andesite extends from a point near the Thirty-fifth Parallel shaft northward to the North Pioneer shaft and the Snow Ball vein, and essentially constitutes the portion of the hills between the German-American vein on the east and Vivian Wash on the west, with small columnar cappings of the otherwise dominant country rock on the highest points. This rock does not seem to contain important deposits. At the contact of the green chloritic

andesite and the older andesite the transition zone from the unaltered stage of the one rock to that of the other is about a foot wide, the chloritic andesite being here dense, hard, and variously intruded into joint planes and fractures of the older andesite.

On the south faulting seems also to have taken place along the contact, as the eruptive rock occurs in the north face of the Thirty-fifth Parallel drift in the bottom of the mine, where it forms both walls.

The green chloritic andesite also occurs in the bottom of the Treadwell shaft, where it is somewhat altered, soft, pyritic, and traversed by calcite veinlets. The black, unaltered phase is also present, as shown in the dumps.

Veins and ores.—The German-American vein or lode extends practically continuously throughout the length of the Thirty-fifth Parallel, Treadwell, and Pioneer claims, a distance of nearly a mile, and contains free gold practically throughout its extent. Assays of $15 are said to be common and many samples yield up to $30 a ton.

The general strike of the vein is about N. 12° W. and the dip is about 85° E. The vein ranges from 1 to 60 feet in width and consists essentially of calcite, quartz, and adularia, with some brecciated country rock. The calcite is in part replaced by quartz.

The values favor the hanging wall and the best values are mostly associated with the quartz. A microscopic section of the ore shows it to be typical quartz, adularia, and calcite ore. According to a series of analyses of the ore throughout the vein, made by the company, the amount of quartz or silica present is about 17 per cent and calcium oxide (CaO) 27.9 per cent. Like the Gold Road ore this ore is easily mined and milled. An extraction of 92 per cent is reported to have been obtained by cyanidation. It is said that with electricity as power the ore could be mined and milled at a cost of about $2.50 a ton.

The croppings are prominent and where silicified locally rise 20 or 30 feet above the surface, as shown at the Treadwell shaft (Pl. XV, *B*). The following is a cross section of the vein north of the Thirty-fifth Parallel shaft, looking south:

Cross section of German-American vein north of Thirty-fifth Parallel shaft.

	Feet.
Smooth, glossy, slickensided hanging wall, of mottled, firmly cemented, and silicified fault breccia, 3 feet or more in width, composed of crushed country-rock andesite, quartz, and calcite ore; contains $2 or $3 in gold to the ton.	
Impregnated country-rock quartz and calcite ore; contains as a whole $4 to $6 in gold to the ton	8
Main vein chiefly calcite and quartz, somewhat banded toward center; contains $10 a ton	3–4
Greenish porphyritic andesite foot wall, rather freely traversed by stringers and veinlets of calcite and quartz.	

At the Thirty-fifth Parallel shaft the foot wall is usually well defined, solid, smooth, and slickensided. The vein is nearly everywhere frozen to the wall, which consists either of the solid country rock or of 6 inches to 2 feet or more of hard fault breccia composed of crushed rock, spar, and quartz. The hanging wall, on the other hand, is ragged, ill defined, and loose or less firm than the foot wall, and for 20 or 30 feet back from the vein is composed mostly of loosely cemented crushed rock containing veinlets of calcite.

On the 170-foot level, in the north face of the drift, about 200 feet distant from the shaft, the vein pinches to less than 1 foot in width and is not workable.

On the surface south of the shaft it splits or is shattered. A small stringer continues southward on the course of the vein, while the main portion of the vein is turned eastward at an angle of 20° to 30° from its normal course by a fold or small fault; prospects are opened on both parts on claims to the south.

At the Treadwell shaft the vein widens to a lode about 70 feet in width, which it maintains for a distance of about 600 feet. The lode is composed of rock, calcite, and quartz, and although it carries $2 or $3 a ton all the way across and contains several veins 3 to 12 feet wide, only an 8-foot vein on the hanging-wall side is workable. As exposed in a pit 160 feet south of the shaft, this 8 feet of pay ore consists essentially of coarsely crystalline or massive calcite, kidneys or small horses of red country rock, and a little quartz, and runs $9 or $10 a ton, retaining these values to the bottom of the mine. The quartz is of the pale-greenish Gold Road variety and carries the best values. Next to it in value comes the red or reddish iron-stained streaks in the spar. In the Treadwell shaft the vein gradually narrows in depth, the workable portion being only 2 feet in width in the bottom of the mine, 260 feet below the surface.

In Pioneer shaft No. 1, which is 240 feet in depth, the vein, 10 to 12 feet in width, is said to contain 1½ feet of $10 to $14 ore and about 5 feet of low-grade ore. This shaft is now being worked by lessees, who are shipping the ore to Needles. The shaft produces more water than the Treadwell shaft.

Just beyond a small gulch north of Pioneer shaft No. 1 the vein forks; the main or hanging-wall portion continues northward and seems to pinch out near the middle of the Trio claim, while the lesser or foot-wall portion curves to the left, extends northwestward, and forms the Snow Ball vein. In the Snow Ball shaft, which is 100 feet deep, it is said to contain a width of about 1½ feet of $25 to $30 ore and to have produced in pioneer days much very rich ore, some averaging 40 ounces of gold to the ton.

The Hidden Treasure vein, opened on the Hidden Treasure claim, is reported to be about 50 feet in width and to carry a streak of pay

ore on either wall and one in the middle; the latter is about 2 feet in width and is said to contain $60 ore.

VICTOR-VIRGIN MINE.

Location and history.—The Victor-Virgin mine (Pl. XV, *A*; fig. 30) is situated in the southeastern part of the district, 2 miles southeast of Vivian and a mile east of the German-American mine. The elevations range from 2,500 to 2,700 feet. The mine was discovered early in the sixties by Ben Speare, about the time that other mines in this part of the country were staked by the California volunteers then stationed at Camp Mohave on the Colorado. The property comprises two claims, the Victor and the Virgin, both patented. It was formerly owned by Charles Goodchild and is now owned by the Victor Gold Mining Company, of Denver. A small amount of rich ore has been shipped and much milling ore lies on the dump.

Developments.—At the time of visit (January, 1907) the mine was developed to a depth of nearly 300 feet, principally by two shafts and drifts. The shafts are known as the Victor and Virgin and are situated about 850 feet apart on the vein, the collar of the Virgin being about 100 feet above that of the Victor. Each shaft contains more than 300 feet of drifts. The Victor shaft produces some water, which was encountered in crosscutting to the vein 14 feet distant from the shaft on the 200-foot level.

At a point midway between the Victor and Virgin shafts, however, a new double-compartment shaft had just been started, and at present writing (June 22, 1908) is reported to have reached a depth of 500 feet; at this level the management is crosscutting to tap the vein.

The principal surface equipments at the time of visit were gasoline hoists at the Victor and Virgin shafts. Elaborate equipments, however, were then being added, including the installation of a 650-horsepower steam plant at Needles, 16 miles distant, the erection of a 20-stamp mill near the new shaft at the mine, and pipe-line connections between Colorado River and the mine and mill. The plant seems rather extensive for a mine of this size, in which the deposits have not yet been shown to extend to any great depth. The power plant at Needles will supply power and pump the water from the river to the mine and mill. It is expected that the power can be supplied at a cost of $6 per horsepower per month.

Country rock and veins.—The country rock is principally the green chloritic andesite, with the underlying older andesite occurring near by on the west. A little pyrite was observed locally in the green chloritic andesite, but none in the vein.

The Victor-Virgin vein lies chiefly in the green chloritic andesite and possibly in part on the contact between this rock and the older

A. VICTOR-VIRGIN MINE, LOOKING NORTH.

Victor shaft to the left, Virgin to the right.

B. GERMAN-AMERICAN MINE, LOOKING SOUTH.

Treadwell shaft to the right; Thirty-fifth Parallel shaft left of center. Boundary C[illegible] shows through gap.

andesite. The vein strikes N. 47° W. and dips 80° NE. to 90°. It is reported to be more than 3,000 feet in length, varies from 1 to about 18 feet in width, and is locally associated with silicified country rock or breccia 100 feet or more wide.

The vein is of the Gold Road type, being composed principally of quartz and microscopic adularia with a small percentage of calcite and crushed rock. As seen in the Victor shaft and vicinity the calcite is usually best developed on the foot-wall side of the vein, where in places it is a foot or more in width.

The croppings are usually prominent and consist of the common dark-stained quartz, calcite, and silicified country rock, of which a cross section northwest of the Victor shaft follows:

Cross section of Victor-Virgin croppings northwest of Victor shaft.

	Feet.
(*a*) Dull greenish and purplish porphyritic hanging-wall green chloritic andesite, bearing amygdules and crystals of calcite and scattered amygdules of quartz; in the last 5 or 6 feet to the right stringers of chiefly calcite and some quartz, ⅛ inch to 4 inches thick, trending nearly parallel with vein and feeding downward gradually into it	100+
(*b*) Silicified rock and impure quartz, brownish and greenish chloritic andesite, etc., traversed by some of the above-noted calcite-quartz stringers	3
(*c*) Breccia of greenish and reddish stained quartz, crushed and firmly recemented	1
(*d*) Andesite same as *a*, with crossing calcite veinlets ¼ to 1 inch thick	2–3
(*e*) Silicified calcite and fragments of country rock *a* or *d* and quartz frozen to foot wall	1½–2
(*f*) Country rock same as *a;* near vein is more silicified and finer grained and locally crushed and recemented; at 10 feet distant from vein carries a calcite-quartz stringer 1 foot thick and two smaller ones	100+

The section in the face of the west drift on the 200-foot level of the Victor shaft consists of about a foot of dull greenish-gray crushed and recemented quartz and calcite and 9 inches of brecciated gouge; it is usually frozen to the hard walls, the hanging wall containing stringers or veinlets of calcite that feed downward into the vein.

On the 100-foot level the vein is about 7 feet in width west of the shaft, while east of the shaft it is about 4 feet in width, and the hanging wall shows horizontal slickensides.

The ore shoots are reported to dip steeply to the southeast. The ore contains gold and locally shows copper stain, but no pyrite was observed in it. In the thin section the ore is seen to be a typical quartz-adularia ore with a few calcite grains present.

The ore is said to be mostly of medium grade, but it ranges from $9 to about $60 a ton. Some of the greenish quartz croppings near the Victor shaft are reported to have assayed $100 a ton.

TOM REED MINE.

Location and history.—The Tom Reed (formerly Blue Ridge) mine (Pl. XIII, *A*) is situated in the eastern part of the district, about a mile south of the Gold Road mine and about 200 feet below it and nearly a mile northeast of the Victor-Virgin mine. It lies on open ground in Blue Ridge wash near the base of the central part of the range, at an elevation of 2,700 feet.

The mine was discovered about 1900 and was soon after owned by Ely Hilty, Walter Fellows, Walter Hawkins, Jacob Anderson, and others. About 1901 the Gold Road Company sunk the two principal shafts on the property, the Ben Harrison and the Tom Reed, each to a depth of about 100 feet. The ore in the first 30 feet of the Ben Harrison shaft averaged $25 a ton and for the rest of the depth $12 a ton. About 1904 the mine was purchased from the Hilty party by the Blue Ridge Gold Mines Company, which installed a mill and operated the mine and mill for about a year and a half with about eighteen men, and milled on an average about 30 tons of $7 ore a day. As considerable gold remains in the tailings produced during this period the ore should be treated by cyanidation. In 1906 the Blue Ridge Company was succeeded by the present owner, the Tom Reed Gold Mines Company, with headquarters at Pasadena, Cal. In 1908 the mine was reported to be working steadily, sinking, and producing gold bricks regularly. More recently a body of $12 ore 12 feet wide is said to have been encountered on the 300-foot level.

The property comprises a group of eleven claims, adjoining one another end on and extending along the vein for a distance of about 3 miles. The production is reported to considerably exceed $120,000.

Developments.—The mine is located near the middle of the claim group on the Ben Harrison and Tom Reed claims and is developed to a depth of 185 feet, principally by the Ben Harrison and Tom Reed shafts. The developments aggregate about 600 feet of underground work, done mostly in 1904 to 1906. The shafts are located about 600 feet apart, on or close to the vein. The Ben Harrison shaft, whose workings practically constitute the mine, contains about 400 feet of drift, distributed on three levels 50, 100, and 150 feet below the surface.

The mine is said to produce about 5,000 gallons of good water a day, ample for operating the mill. The water level lies about 100 feet below the surface. A never-failing spring, the Olla Oatman, is said to occur on the property.

The principal surface equipments are a 40-ton 10-stamp mill (of 1,050 pounds per stamp), with an 85-horsepower Corliss oil-fuel engine and a 100-horsepower boiler, a 15-horsepower gasoline hoist, tramways, and necessary buildings. It was lately reported that 20 new stamps have been added and that the mine is being supplied with power from the plant at Kingman.

Geology and veins.—The country rock is the green chloritic andesite containing amygdules of calcite. The Blue Ridge vein strikes about N. 50° W. and dips about 70° NE. It lies nearly parallel with the Gold Road vein on the north and with the Victor-Virgin vein on the southwest, to both of which it is geologically and mineralogically similar. On the Tom Reed property it has an extent of about 3 miles, and it is said to continue as the Pasadena vein on the northwest, in which event it has a total length of about 4½ miles, being probably the longest vein in the district. At the Tom Reed mine it ranges from about 16 or 20 feet in width in the Ben Harrison shaft to about 35 feet in the Tom Reed shaft, with the fissure walls usually ill defined. It outcrops boldly for the length of two claims. The croppings consist principally of the usual dark iron and manganese stained quartz and silicified rock, calcite, and chert. On the foot-wall side they are markedly cross sheeted.

The vein is mainly of the Gold Road quartz-adularia type, with but little calcite present in the principal part of the mine. A considerable portion of it is reported to have run $25 in gold to the ton for the first 30 feet in depth and about $12 from that point down. Although gold only is produced, the ore contains also a little silver.

In the Ben Harrison shaft the vein shows a total width of 16 to 22 feet, and the only well-defined wall is the foot wall on the 50-foot level. This wall has about 1 foot of crushed rock and quartz as gouge and a 1½-inch band of silicified brown or red rock between it and the vein, which shows a thickness of about 3 feet of quartz ore and 3 to 4 feet more of intermingled crushed rock and quartz.

On the 100-foot level the vein consists of 16 feet of crushed quartz and rock with neither wall at all defined; but toward the hanging-wall side of the vein there is 6 feet of good-looking, more or less porous, clear quartz ore, as shown in the accompanying section.

Section of portion of Blue Ridge vein in Ben Harrison shaft on 100-foot level.

	Feet.
Crushed rock with some frozen quartz, but no foot wall.	
Massive quartz	2½
Rock horse, reddish brown	1½
Crushed rock	2
Crushed rock with quartz stringers	2½
Partly crushed, porous, and honeycombed quartz ore, which somewhat resembles Gold Road ore	6
Crushed rock.	

On the 150-foot level the vein consists mainly of crushed rock; but the foot-wall side of the drift is in quartz; the hanging wall carries some vugs 6 inches to 1 foot in diameter, containing blackish, porous, and oxidized quartz ore.

In the crosscut at the bottom of the Tom Reed shaft, situated on the hanging-wall side of the vein, the following section is shown:

Section in crosscut at bottom of Tom Reed shaft.

	Feet.
Silicified andesite foot wall represented on the surface by the bold, dark croppings.	
Reddish-stained quartz and crushed rock containing, it is said, about $80 in gold to the ton	6
Crushed rock and spar	20+
Crushed andesite country rock and some spar with no definite hanging wall.	

A fine body of ore is reported to have been recently opened near the Tom Reed mine, on the Shuck & Darling property.

MIDNIGHT MINE.

The Midnight mine is situated in the hills 1½ miles northwest of Vivian, at an elevation of 2,500 feet, and is accessible by wagon road. It is owned by the Mohave Gold Mining Company, and has been producing moderately since about 1900. For some time it paid the running expenses of the Leland mine, which were large.

The mine is developed to a depth of 50 feet by inclined shaft, drifts, and stopes and is equipped with a gasoline hoist; the management has just begun sinking the shaft 300 feet deeper.

The country rock is the green chloritic andesite. It is intruded by basic and acidic dikes near by and is cut by a marked sheeting which trends N. 10° W. and dips 75° W. and by a close cross sheeting which dips steeply to the north. One of the basic dikes, a fine-grained greenish rock, about 40 feet in width, forms the foot wall. About 300 feet northeast of the mine, on higher ground, occurs a closely banded bluish to light-gray and greenish mottled 2 to 3 foot vein composed of fine-grained siderite containing some lime and manganese. It resembles rhyolite with banded or flow structure and may have replaced a dike in the fissure it now occupies.

The Midnight vein, which is the foot-wall member of a north-south lode, 100 feet wide, strikes N. 15° W. and dips 30° to 40° W. It is about 3½ feet in width and consists principally of quartz, with some calcite, fluorite, and adularia. Its foot-wall portion, for a width of 3 or 4 inches, contains crudely banded red and green fluorspar, and toward the foot wall the quartz becomes dark and dense, of a flinty nature, and contains a few crystals of pyrite.

The vein has been worked from the surface almost to the bottom of the mine and longitudinally for a distance of about 120 feet, mainly on the south side of the shaft, and in this extent has averaged about $18 a ton in gold. The production has been considerable for a mine of its size, that on one side of the shaft alone amounting to $18,000. Where now worked in the bottom of the mine the ore is of low grade, running about $7 in gold to the ton, and consists of a mixture of partly altered soft country rock traversed by stringers and veinlets of calcite and quartz.

VIVIAN MINE.

Location and history.—The Vivian mine is located on the Vivian claim about one-fourth of a mile below Vivian. It is west of Vivian Wash, on the Mohave and Milltown Railroad, at an elevation of about 2,200 feet. Its position and topography are shown in Plate X.

The mine was discovered about 1902 by Ben Paddock, a half-breed Mohave Indian, who in riding over the trail at the locality observed glittering free gold in rich croppings which had been disturbed by a recently passing wagon. He at once located a claim, later known as the Vivian, and took with him to Camp Mohave that day as much of the croppings as he could conveniently pack on his pony, from which it is said that he obtained about $500 in gold. Soon afterward a considerable amount of gold was extracted from the rich croppings and surface ore found on the claim. In 1903 the mine was purchased by Judge E. M. Ross and Col. Thomas Ewing, who developed it to some extent, and in 1905 sold it to the Vivian Mining Company, with headquarters at Los Angeles. The company continued to develop the property and installed a mill whose completion in the spring of 1906

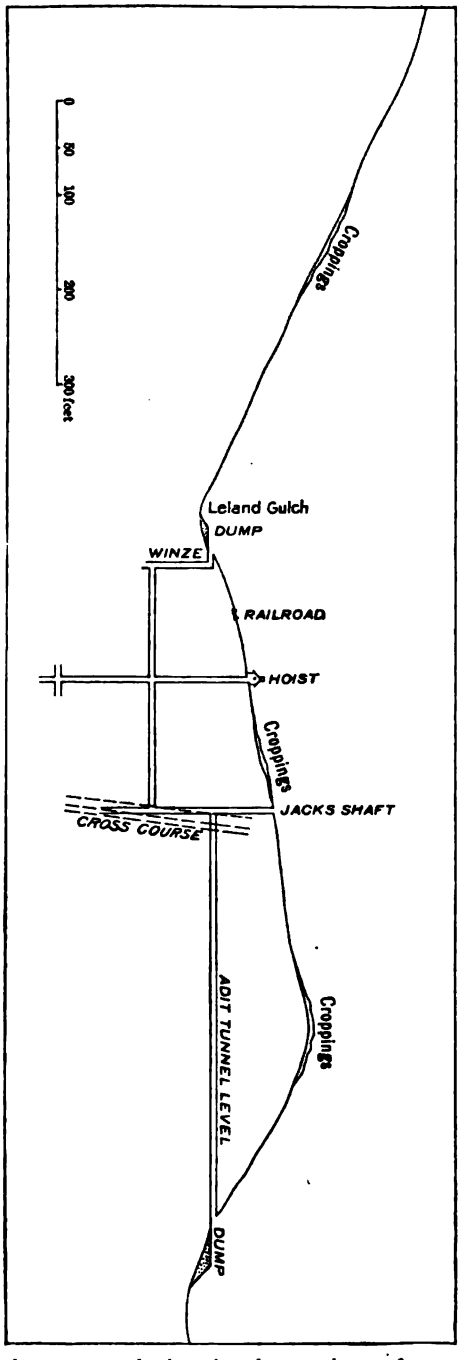


FIGURE 31.—Longitudinal section of workings of Vivian mine.

was followed by a run of forty days, after which the plant and mine were closed in July, it is said, for lack of water. The production is small.

Developments.—The mine is developed principally by three shafts and drifts to a depth of about 270 feet (fig. 31). The principal equipments, which, unfortunately, seem to have been prematurely installed, are new, of the best modern type, and very complete, and include an automatic 40-ton 10-stamp mill and cyanide plant, with a 200-horsepower Scotch marine boiler, Hamilton-Corliss engine, hoist with double engine, air compressor, ore crusher, bullion furnace, and commensurate attachments, to all of which may be added the advantageous location of the property on the railroad already mentioned.

Geology.—The country rock is the green chloritic andesite, which in the gulch just west of the mine gives way to the older andesite. The green chloritic andesite is probably intrusive in the older andesite, but the contact at the mine seems to be in part a fault plane. The older andesite rises about 40 feet above the gulch and extends from a point 200 feet above the mine to a point several hundred feet below it. The green chloritic andesite in the mine is pyritic and in part brecciated and somewhat altered.

Veins.—The Vivian vein strikes N. 75° W. and dips about 80° to 85° S. It has a known extent of about half a mile. It is 3 feet in average width, which is less than that of most of the veins in the district, and west of the mine it narrows to a mere stringer. It consists essentially of coarsely crystalline dark calcite and a little quartz.

The croppings have a thickness of up to 2½ feet of stained red and black quartz, rising to a maximum of 3 feet above the surface. A considerable amount of the quartz is pseudomorphic after calcite. The walls, especially the foot wall, are not well defined and contain coarsely crystalline calcite in the fractures and joints. A lack of continuity of vein and ore, which is said to be characteristic, is an unfortunate feature of the deposit. It is, however, very rich in spots.

The gold contained in the vein varies from very fine to coarse colors, wire gold, and small clumps, and occurs chiefly in pockets or bunches ranging from low to very high in value, as high as $9,500 a ton being reported. The higher values occur in the quartz and are best in the quartz that is associated with the dark spar.

The principal dumps show that the older and site has been encountered, from which it seems doubtful whether workable ore will be found at greater depths.

SWISS-AMERICAN MINE.

History and developments.—The Swiss-American mine is located at Vivian, in the base of the hills on the east side of Vivian Wash. The

mine was acquired from the locators by its present owner in 1891. Masses and fantastic forms of free gold are reported to have been found plentifully in its croppings and surface ore at the time of discovery and caused a considerable sensation. It is owned by the Swiss-American Mining Company, of Fremont, Ohio. This company is said to operate also a large silver mine and smelter in Sonora, Mexico. The production is probably small and has been obtained chiefly from the Bonanza shaft.

The principal developments are two shafts, the Ben Doran and the Bonanza. The former is 100 feet in depth and contains two 20-foot crosscuts to the north and to the south at the bottom. The Bonanza, situated 40 feet to the north of the Ben Doran, is but 16 feet deep. The principal equipments are a gasoline hoist.

Country rock and vein.—The principal country rock is the green chloritic and pyritic andesite, but the older andesite is also present.

The deposits are contained in what seems to be the eastward extension of the Leland vein, on whose course the mine and croppings are located, but at this locality the vein partakes more of the nature of a lode, shear, or compound fracture zone than of a simple fissure vein. To judge from the croppings the lode is about 200 feet in maximum width. It strikes N. 65° W., dips about 65° N., and is cut by a sheeting that dips steeply to the west and also a closer sheeting resembling cleavage that dips steeply to the east.

The lode is, in places, divided in two parts by faulting along its median line; for example, just south of the Ben Doran shaft the smooth slickensided hanging-wall side of the southern half of the lode, exposed for about 50 feet, contains 1½ to 2 feet of impure quartz and crushed rock.

The croppings of the lode consist principally of silicified rock and stained quartz. The most prominent of the croppings are comprised in a width of about 50 feet on the north or hanging-wall side. This portion rises about 20 feet above the surface of the wash and contains bodies of unaltered as well as silicified rock with stringers and veinlets of quartz and calcite, principally in the silicified rock. It contains also the workable and in part rich portion of the vein, which is reported to be about 13 feet in width, with principally quartz gangue frozen to the walls.

At a short distance east of the mine the lode is cut by a cross fault, which has seemingly carried the eastern portion 100 feet or more to the south and downward. Longitudinally, however, the croppings in general continue interruptedly eastward up the gulch and hill slope toward the German-American mine.

As the shaft was boarded up from the surface nearly to the bottom, underground observation was here restricted to the crosscuts at the bottom of the shaft, which lie in the older underlying ande-

site. A horizontal contact is reported between this rock and the green chloritic andesite 60 feet below the surface.

The only representation of the great Leland vein found here in the bottom of the mine is a stringer of partly vuggy quartz and calcite 1½ feet wide, containing very low values only, in the south crosscut and a 1 to 2 inch quartz stringer in the north crosscut, from which on the whole it seems probable that no workable ore occurs at greater depth. As stated on page 187, in the description of the German-American mine, there seems to be little prospect of any deep or important ore deposits being found between Vivian Wash on the west and the German-American vein on the east.

The Bonanza shaft, at the north or hanging-wall edge of the lode, is located on a small east-west shear zone, fault vein, or stringer, about a foot in width, consisting of altered silicified rock, impure iron-stained quartz, and calcite, and is associated with a parallel 10-inch dark dike rock. The ore of this little "vein" is reported to have contained free coarse gold in abundance, the richest being found in the iron-stained portion of the vein, but, as in the Ben Doran shaft and others, owing to the proximity of the older underlying andesite, it seems probable that the ore does not continue to great depths.

ROOSEVELT SHAFT.

The Roosevelt shaft is about three-fourths of a mile north of Vivian, in the hills on the upper drainage of Vivian Wash, on the Roosevelt claim, at an elevation of about 2,500 feet. The country rock is the green chloritic andesite. The deposits are contained in a calcite and quartz vein, which strikes N. 25° W., dips about 60° WSW., and is reported to be at least 30 feet in width where it is crosscut on the 100-foot and 200-foot levels. The vein is separated from the fissure walls by a well-marked sheet of talcose gouge. It is developed by a shaft 200 feet in depth. Both the country rock and the vein contain pyrite, which in the rock is finely disseminated, while in the vein it occurs in coarse sporadic crystals.

BOUNDARY CONE DISTRICT.

GENERAL DESCRIPTION.

The Boundary Cone district lies in the southwestern part of the region, just south of the Vivian district, from which it is separated by Boundary Cone Wash. It extends from the edge of the mountains at Boundary Cone (Pls. X, XVI) on the west, 3 miles eastward, nearly to the crest of the range, and from Boundary Cone Wash southward nearly to McHeffy Butte, about 4 miles distant.

A. TOPOGRAPHY OF ANDESITE IN NORTHEASTERN PART OF BOUNDARY CONE DISTRICT, LOOKING NORTH FROM POINT NEAR HIGHLAND CHIEF MINE

Krauss camp and mine in foreground.

B. TOPOGRAPHY OF ANDESITE FLOWS IN SOUTHERN PART OF BOUNDARY CONE DISTRICT, LOOKING SOUTHEAST FROM BOUNDARY CONE.

The deposits occur principally in the northern part of the district. Here the topography is mostly rugged, of the type of eroded volcanic flows, with the mountains rising 1,500 to 2,000 feet above the intervening washes, through which the drainage issues northwestward into Boundary Cone Wash and thence westward to the Colorado (Pl. I). By means of the washes, which serve as highways, the properties are nearly all reached without difficulty, most of them by wagon.

The country rock is mainly a dense dark reddish-brown or purple andesite, locally known as "phonolite" from its metallic ring when struck, and is underlain principally by the earlier tuffaceous andesite containing agglomerates and breccias, below which the pre-Cambrian granite is exposed on the extreme west. These rocks are all intruded by rhyolite in the form of plugs and dikes, of which Boundary Cone is a typical example. The outer basal portion of the cone is composed of andesite tuff; the inner, upper portion, rising to a height of several hundred feet above the andesite, is a huge rhyolite plug, from whose periphery dikes radiate into the surrounding andesite, a good example being on the northwest slope, where a siliceous dike about 15 feet in width extends for three-fourths of a mile to the wash on the west. The andesite for a width of a few inches or a foot along the contact is altered and iron stained. The andesite is also cut by dikes of a younger andesite, derived from a magma the same as or similar to that of the country rock.

The structure in the country-rock andesite varies. In Mount Tucker, at the Iowa mine, in the northeastern part of the district, it consists principally of a sheeting which dips steepy to the south, a secondary sheeting which dips about 70° ESE., and a very marked cleavage, locally amounting to schistosity, which trends about N. 60° E. and inclines with low variable dips to the south-southeast.

The microscope shows the country rock to be a greatly altered andesite, composed principally of a fine-grained groundmass varying from trachytic to cryptocrystalline and containing small glassy or whitish feldspar phenocrysts. Fresh augite andesite was noted from the Highland Chief property.

The principal needs of the district are water and fuel. The chief source of the water supply at present is a few small springs located near the core or crest of the range.

The deposits are gold bearing and occur in two distinct types—as fissure veins in the purple andesite and as deposits on the contact of the rhyolite intruded into the andesite, andesite tuff, and granite. The gangue consists principally of fine-grained quartz with adularia and calcite.

The principal veins, five or six in number, occur in the northeastern part of the district. They strike in general west-northwest and

have steep dips. Some of the important properties or openings located on them are the Iowa, Lazy Boy, Krauss, Highland Chief, and Mountain Beauty.

IOWA MINE.

The Iowa mine, which is the most extensively developed, is situated in the northeastern part of the district at about 2,670 feet elevation, near the top of a nearly east-west ridge, about 140 feet above a tributary gulch on the northeast that leads northward into Boundary Cone Wash. It is about 3½ miles southeast of Vivian, the principal supply point, with which it has good wagon-road connections.

The property comprises three principal claims, the Iowa, Gold Cup, and Gold Nugget, known as the Iowa group. It was located in 1902 by Moore, Roberts, and Hunt, who still own it. Since 1904 it has been bonded to C. E. Hymer and S. W. Wood. It is developed principally by a 200-foot shaft and about 100 feet of drifts and crosscuts, distributed on three levels, and is equipped with a 6-horsepower gasoline hoist.

The country rock is the dense, reddish-brown, porphyritic andesite.

The deposits are contained in a fissure vein, which dips steeply to the south and is exposed by the croppings for more than half a mile. It ranges from 3 to 8 feet or more in width and consists principally of greenish brecciated quartz and a little calcite, with locally some rock breccia, and is traversed by veinlets of secondary quartz and calcite. The values, said to range from about $3 to $14 in gold to the ton, are found mostly within 3 feet of the hanging wall. Some faulting or displacement has occurred along the vein, where pronounced slickensiding shows the movement to have been normal.

On the 100-foot level at a point 10 feet west of the shaft the drift, including the 16-foot crosscut to the south in the hanging wall, shows the following section:

Section on 100-foot level in Iowa mine.

	Feet.
Andesite, crushed and sheared, forming foot wall.	
Crushed and brecciated quartz and andesite with veinlets, containing from $5 to $6 in gold to the ton	6
Horse of coarsely porphyritic andesite	9
Partly crushed and relatively clear quartz, probably with adularia, running about $3.50 in gold to the ton	7
Hanging wall of country-rock andesite.	

On the 200-foot level the crosscut, extending 12 feet to the south in the hanging wall, exposes the following sections:

Section on 200-foot level in Iowa mine.

	Ft.	In.
Andesite foot wall.		
Finely comminuted andesite and quartz containing $2 in gold to the ton		10
Crushed quartz and andesite, which is similar to the above, but on its hanging-wall side becomes a coarser and purer quartz and contains $14 in gold to the ton	2	
Partly crushed and sheared silicified andesite with fine stringers and veinlets of calcite and quartz	9	

LAZY BOY GROUP.

The Lazy Boy group, comprising four claims owned by F. L. Hunt and J. H. Moore, is on the opposite side of the ridge and about one-fourth of a mile southeast from the Iowa mine, at an elevation of 2,600 feet. It is reached by trail from the Iowa mine or from a tributary of Krauss Wash on the southwest. The property is now bonded to S. W. Wood. It is developed principally by a 43-foot shaft and an open cut.

The country rock is the dense, reddish-brown andesite characteristic of the district. The vein strikes N. 85° W. and dips about 80° S., nearly parallel with the Iowa vein. The cut exposes a width of about 6 feet of vein material, composed mostly of brecciated andesite and quartz, said to contain fair values in gold; in the shaft the vein contains several feet of excellent-looking greenish and iron-stained quartz or, which is in part brecciated, contains a little calcite, and probably adularia, and is said to average about $9 in gold to the ton.

HIGHLAND CHIEF AND MOUNTAIN BEAUTY PROPERTIES.

The Highland Chief property is located in the eastern part of the district, about 1½ miles south of the Iowa mine, in the heart of the range, at about 2,850 feet elevation, at the head of Krauss Wash, which drains northwestward into Boundary Cone Wash. It is owned by the Heck Mining Company, of which Casper Heck, of Vivian, is a leading member.

The country rock is andesite, and it is intruded by a similar somewhat younger rock. The vein strikes northwest and stands about vertical, but locally exposes a good foot wall dipping to the southwest at angles of about 70°.

The croppings are strong and bold, particularly to the southeast of the mine. They consist of stained, crushed, and greatly sheared quartz. The property is developed principally by a 70-foot drift,

in which the vein contains some good-looking greenish quartz ore, said to carry fair values in gold.

The Mountain Beauty property, owned by the same company as the Highland Chief, is located about half a mile northwest of the Highland Chief, at about 2,650 feet elevation, 1,000 feet above the main wash that issues westward south of Boundary Cone. The place is difficult of access. The vein, where examined at the head of a tributary wash on the north, strikes N. 80° W., is 12 to 15 feet in width, and consists principally of yellowish and brown iron-stained crushed or brecciated rock and quartz reported to contain fair gold values.

KRAUSS AND GOLDEN ERA PROPERTIES.

The Krauss and Golden Era properties, not visited in this work, seem from oral reports to be similar to most of those just described. The Krauss property, owned by Joseph Krauss, of Vivian, is about half a mile southwest of the Iowa mine, on Krauss Wash and the adjoining hill slope to the northeast, where the dumps show considerable work done. The Golden Era property is about 4 miles southeast of Boundary Cone, at about 2,500 feet elevation.

DEPOSITS AT THE ANDESITE-RHYOLITE CONTACT.

The deposits at the contact occur chiefly in the western part of the district. They are best exposed along the upper edge of the andesite collar encircling the rhyolite plug that forms the upper part of Boundary Cone. They occur mainly on the west and south sides of the cone, where at about 2,400 feet elevation they extend interruptedly for about a mile and are not usually accessible by wagon.

The deposits occur chiefly in a zone of greenish quartz located principally on the rhyolite side of the contact. The quartz zone is 6 to 10 feet in width. It locally contains from $3 tc $17 in gold to the ton, with some $200 values reported, and some of the quartz shows free gold. The rhyolite for a width of 2 or 3 feet next to the quartz also contains values.

The Kyle property, opened to a depth of 10 feet on the west side of the cone, exposes a width of 6 feet of good-looking rhyolite and iron-stained, greenish, crushed or in part brecciated quartz with some intermingled rhyolite. Here the deposit dips inward toward the center of the cone at an angle of about 60° and is said to average $17 in gold to the ton. Similar openings also extend around the west and south sides of the cone.

The Warner prospect, reported to contain good values, is about half a mile southwest of Boundary Cone, in association with what

seems to be a rhyolite dike cutting the pre-Cambrian granitoid complex and remnants of overlying rocks.

UNION PASS DISTRICT.

GENERAL DESCRIPTION.

The Union Pass district (fig. 32) lies about 30 miles west of Kingman, mainly on the west slope of the range. It extends from Sacramento Valley and Union Pass westward to Colorado River at Pyramid, a distance of about 14 miles, and has a width of about 3 miles. It ranges in elevation from 4,000 feet on the east to 500 feet on the west. On the east the topography is rough and mountainous, of the type of dissected volcanic flows, with local fault scarps and deep gulches. On the west the district is composed of low hills, broad, open washes, and gravel-covered areas sloping toward the river. Important well-known landmarks are Union Pass on the northeast; Thumb Butte, a rhyolite needle, on the south, to which most of the claims of the district are tied; and Pyramid Rock, a survey benchmark at the river, on the west. A cross

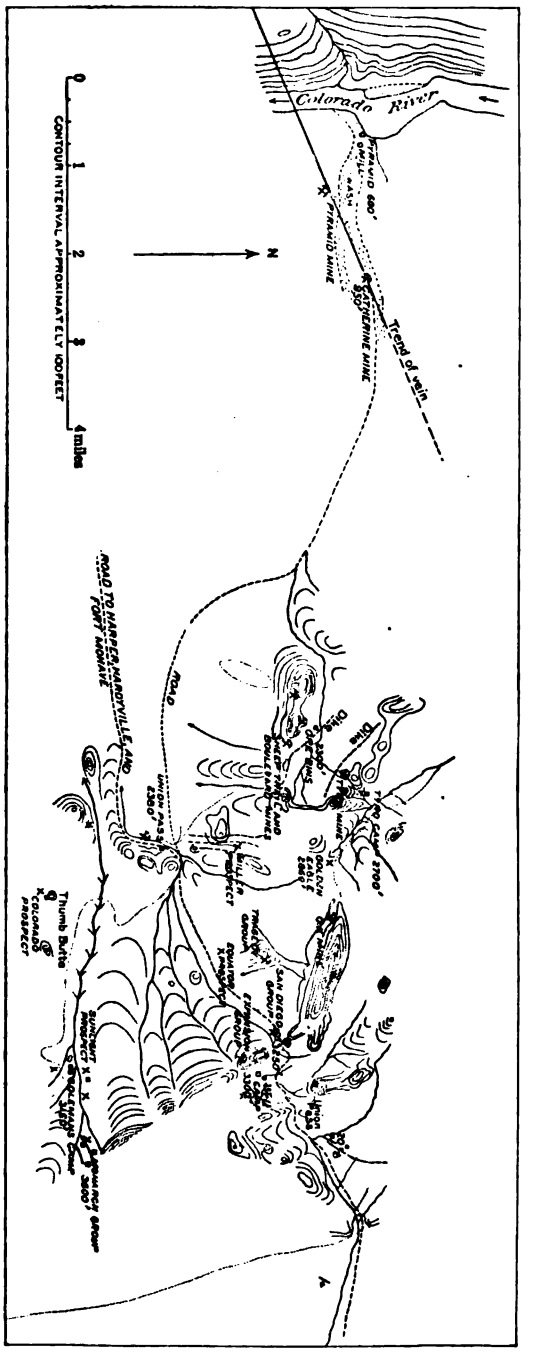


FIGURE 32.—Sketch map of Union Pass mining district.

section of the range at Secret Pass, southeast of Thumb Butte, is given in figure 33.

The water supply is scanty, except near the river. On the east it consists of a few springs or shallow wells in the mountains. The country rock on the northwest and on the south is the pre-Cambrian granitic complex, but in the remainder of the district, especially on the east, it is more or less deeply buried by heavy deposits of the Tertiary volcanic rocks, here consisting principally of rhyolite.

On the west the deposits occur in fissure veins in the pre-Cambrian granite. On the east they occur also as blanket veins, lodes, and irregular bodies and are found chiefly on or near the contact of the rhyolite and granite associated with diabase, a later intrusive, and in conjunction with one or more of these intrusives on fault planes.

The most important of the deposits on the west trend northeastward, those on the east northwestward, and those intermediate in position about midway between these two directions. The prevailing gangue is calcite, which is locally replaced by quartz and adularia.

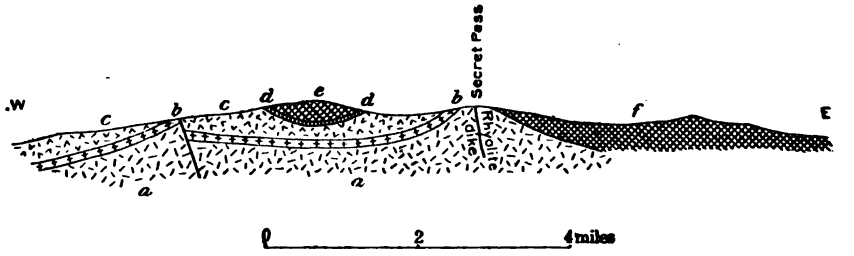


FIGURE 33.—Section across Black Mountains at Secret Pass. *a*, Granite; *b*, biotite andesite; *c*, andesite; *d*, andesite tuff; *e*, rhyolite; *f*, rhyolite and andesite (undifferentiated.)

The metal contained is gold. The deposits were probably formed by circulating thermal solutions, which accompanied and followed the invasion of the intrusives, especially the rhyolite.

MINES IN THE WESTERN PART.

The principal properties in the western part of the district are the Sheep Trail, Boulevard, Catherine, Pyramid, and Tyro. This part of the district has produced considerable ore, most of which has come from the Sheep Trail, Boulevard, and Catherine mines.

SHEEP TRAIL AND BOULEVARD MINES.

The Sheep Trail and Boulevard mines, a property comprising five patented claims and a mill site at the river, are situated near the middle of the district, about 7 miles east of the river, at an elevation of about 2,400 feet, in a group of outlying hills. The Sheep Trail mine was discovered in 1865 by Jack Mellen, a steamboat captain running on Colorado River. The group was later acquired by the

New Comstock Mining Company, which improved the property, installed a 20-stamp mill at the river, and milled about 2,000 tons of ore. In 1904 the Arizona-Pyramid Gold Mining Company, of San Francisco, took hold of the property and has recently milled much ore from the property, principally from the Boulevard mine.

The Sheep Trail mine is developed to a depth of 428 feet by drifts, tunnels, and shafts, aggregating, it is said, more than 5,000 feet of underground work, the lower tunnel being about 750 feet long. Its vein lies in a nearly east-west ridge of pre-Cambrian granite, rising several hundred feet above the adjacent open washes, with intrusive rhyolite near by. The vein dips about 60° S. The ore contains chiefly quartz and hematite as gangue, and is said to be rich. It is hauled to the Sheep Trail 20-stamp mill and cyanide plant, originally built for this mine at Pyramid. Several thousand tons of ore are reported to have been milled.

The ore of the Boulevard mine, whose production is considerable, is also reported to be very rich, some of it containing, it is said, about $50 in gold to the ton. The mine was a producer in 1906.

CATHERINE MINE.

The Catherine mine is about 1¾ miles east of the river and about 450 feet above it, on an open, gravel-covered slope about three-fourths of a mile from the hills to the south at an elevation of 950 feet. The mine was discovered by S. C. Baggs in September, 1900, and soon afterward some development work was done in taking out surface ores, mostly in the 60-foot incline. It was operated by the New Comstock Mining Company, under whose management it is said to have produced about 2,000 tons of ore, which was milled in the Sheep Trail mill at Pyramid. In 1904 the present owner, the Arizona-Pyramid Gold Mining Company, acquired the property, together with the mill at the river, and at once began more extensive development work. It installed a 22-horsepower gasoline hoist, compressor, and fan ventilator, deepened the shaft, and was soon mining and milling systematically. The source of power used is fuel oil freighted from Kingman.

The mine is developed principally by a shaft 225 feet in depth, several hundred feet of drifts and crosscuts, and about 20,000 cubic feet of surface work. The principal equipments are the Sheep Trail mill at the river and the gasoline hoist already mentioned, together with shops, offices, buildings, etc. The camp is at the river, where an ample water supply is available for all purposes.

The country rock is red, coarse pre-Cambrian gneiss or pressed granite and consists essentially of orthoclase, quartz, biotite, and microcline. The vein or lode containing the deposits strikes N. 64° E. At the mine it is about 75 feet in width at the surface, but gradually

narrows downward to 50 and 40 feet on the 100-foot and 200-foot levels, respectively. By reason of the overlying gravels, the vein is exposed for a length of only 150 feet. However, it is in alignment with and is probably a continuation of the Pyramid vein, which, beyond the edge of the gravel sheet, extends southwestward for a distance of several miles, a portion of it lying beyond the river about where the Homestake mill is located. The occurrence of similar ore in alignment on the northeast suggests that the vein may have an extent of nearly 5 miles. In the mine the vein is faulted in places and the fault planes are slickensided.

The vein consists mainly of quartz, mostly replacing calcite; the ore on the whole resembles that of the Gold Road mine, and consists of fine-grained quartz and adularia. Much of the quartz is of the bladed or hackly form characteristic of replacement after calcite.

A microscopic section of the ore shows quartz with comb structure deposited on a mass of granular quartz and adularia containing residual calcite. There are also grains of a black mineral which is probably argentite.

The croppings, which are in part prominent, consist of dark-brown or black iron and manganese stained quartz. Some of the ore is irregularly banded and cut by close sheeting striking N. 20° E. and dipping about 50° NW.

The greater portion of the ore is of low grade, ranging in value from $6 to $7 in gold and silver to the ton, but toward the north side the vein contains a streak of high-grade ore said to run from 4 to 5 ounces of gold and from 200 to 400 ounces of silver to the ton.

The ore is treated at the Sheep Trail mill at Pyramid. It is believed that under economical conditions the ore can be mined and milled at a cost of about $3 a ton. About 5,000 tons of ore have been milled.

PYRAMID MINE.

The Pyramid mine is near the river, about a mile southeast of Pyramid and about a mile southwest of the Catherine mine. It lies in an open country of low hills of pre-Cambrian granite, at about 700 feet elevation. It was discovered early in the sixties and a 30-foot shaft was sunk on it at that time, but little attention was afterwards paid to it until the discovery of the Catherine mine in 1900. It is owned by the Arizona-Pyramid Gold Mining Company. It is developed principally by a crosscut tunnel, a 60-foot drift, and several shafts.

At the apex of the croppings, which is considerably above the workings, the vein is 35 feet in width. It strikes about N. 70° E., being about in alignment with the vein of the Catherine mine, of which it is supposed to be a continuation, and is reported to have

been traced southwestward to a point 2 miles beyond the river, where it passes under the wash-covered mesa in the east slope of the Eldorado Range.

The croppings are similar to those of the Catherine mine and consist of dark iron-stained quartz and calcite. Dikes of rhyolite follow the croppings.

TYRO GROUP.

The Tyro group is located about 7 miles east of the river, just north of the Sheep Trail and Boulevard mines, in the same group of hills, at about 2,700 feet elevation. It comprises two and a half claims adjoining each other end on. Though the mine had previously been several times located, the first work on it was done by the present owners in March, 1902, about the time they located it. The owners are J. R. Russell, P. F. White, S. R. Davis, and S. W. Basanko, all of Kingman.

The property is developed principally by a 50-foot shaft, a 135-foot crosscut tunnel, and a smaller amount of drift and crosscuts. Water is scarce. The country rock is the pre-Cambrian red biotite-microcline gneissoid granite. It is intruded by rhyolitic dikes near by, which seem to be older than the vein, and the ore is reported to be better in value where the vein crosses the dikes.

The Tyro vein extends throughout the length of the claim group, a distance of nearly 4,000 feet, and dips steeply to the east. It varies from 15 to about 100 feet in width, the average width being about 30 feet. It is joined throughout its extent by imbricating stringers from the northwest and the southeast.

The veins contain principally calcite and a relatively small amount of quartz, which has replaced calcite. Some of the blades or plates of quartz replacing the calcite along the vein are 3 or 4 inches in diameter and occur in laminated masses 6 to 8 inches thick.

The vein on the average contains about $6 in gold to the ton and a little silver; some localities, however, are said to have yielded 11 ounces of gold and 53 ounces of silver. Owing to its general low grade, the ore could be worked only on a large scale.

MINES IN THE EASTERN PART.

The eastern part of the district, being relatively new, is yet for the most part in the prospect or development stage. It is being rapidly developed, however, and several mills are being installed. The deposits here, as already stated, are practically all associated with the contact of the rhyolite intruded into pre-Cambrian granite, with values occurring on both the granite and the rhyolite sides of the contact. The deposits locally form prominent hogback ridges, paral-

lel with the contact, and are associated with the faulting of the country rock.

The principal properties in the eastern and southeastern parts of the district are the San Diego, O. K., Expansion, Tragedy, and Union Pass groups. They are situated on the western slope of the range and are easy of access, being on or near the wagon road leading from Union Pass to Pyramid or Harpers. The deposits occur mainly near the contacts of the rhyolite, andesite, and diabase intruded into the pre-Cambrian granitic complex.

SAN DIEGO GROUP.

The San Diego, O. K., and Expansion groups are all located on what is commonly known as the "mammoth ledge." Starting from the crest of the range at a point about 2 miles southeast of Union Pass, at an elevation of about 3,700 feet, this "ledge" extends to the west-northwest for a distance of about 4 miles. It dips steeply to the northeast and is more or less prominently marked throughout the greater part of its course by southwestward-facing scarps or hog-back ridges several hundred feet in maximum height (fig. 34). To the southwest the country rock is the pre-Cambrian granite complex; to the northeast it is the Tertiary rhyolite.

FIGURE 34.—Cross section of San Diego vein at San Diego mine. *a*, Granite; *b*, diabase; *c*, mammoth ledge of silicified gold-bearing rhyolite; *d*, rhyolite older than *c*.

The San Diego group is situated about a mile west of Union Pass, on the upper steep slope of the range, at 3,400 feet elevation. The property, which comprises about a dozen claims, was located about 1893 by F. J. Todd, from whom it was purchased in 1896 by the present owner, the San Diego Mining and Milling Company, of San Diego, Cal. The underground developments were small and consisted mainly of tunnels and crosscuts to the amount of 200 feet. There is also a shaft 75 feet deep.

At the time of visit a 10-ton mill was being installed.

A cross section showing the relation and attitude of the rhyolite and diabase intruded into the country-rock granite is shown in figure 34. The sequence of events that took place here seems to be as follows: Faulting of the country-rock granite (*a*) and its intrusion and flooding by the older rhyolite (*d*); faulting and intrusion of the diabase (*b*) along the contacts of *a* and *d;* faulting and intrusion of the younger rhyolite (*c*), which is akin to granite porphyry along the contacts of *a*, *b*, and *c*.

The intrusions were accompanied by crushing of the rocks and appear to have been followed by deposition of ores by solutions that

resulted in silicification of the rocks, particularly the younger rhyolite (*c*). The values favor the contacts, especially those of the younger rhyolite, but they occur also in the rocks themselves, in stringers and veinlets in the crushed diabase and the granite. They are contained in a quartz and adularia gangue, with a calcite residue. This gangue, in part, at least, is of the Gold Road type. It is also probable that values may be associated with the pyrites which occur in small stringers and disseminated grains in the diabase.

A large amount of ore is claimed to average from $12 to $15 a ton in gold and to contain a little silver. A shipment of a thousand pounds made to the Needles smelter in October, 1906, is reported to have averaged $56 a ton. Some bunches are said to run very high in values. The ore is believed to be suitable for the cyanide process.

O. K. GROUP.

The O. K. group lies about 2 miles west of Union Pass, at an elevation of 3,600 feet. It almost joins the San Diego group on the northwest, being situated on the continuation of the same hogback ridge, which here is several hundred feet high. At the time of visit it was owned by J. D. Richardson and heirs, of Kingman, but it is reported to have been acquired since by the Gold Pass Mining Company, of Los Angeles.

The property is developed mainly on the northwest, at the end of the ridge, which here falls off in steep slopes into a deep valley, beyond which the deposits have not been traced. The developments consist mainly of two tunnels driven on or near the contact of the intrusive rhyolite with the granite. The drifts are situated about 50 feet apart vertically. The upper has a length of 150 feet and the lower of about 250 feet. From the upper a winze descends to or near a crosscut in the lower.

The ore consists of iron-stained and pyrite-bearing quartz and altered rock, and locally contains also some galena. It is irregularly distributed or pockety. That taken from the upper drift, which looks better than the lower drift, is said to have averaged about $20 a ton in gold, and samples of the foot-wall granite taken 10 feet apart throughout the length of the drift are reported to have assayed from $1 to $4 a ton. Some high-grade ore occurs in small bodies of fine sandy material inclosed by the iron-stained lower-grade ore, quartz, and rock.

EXPANSION GROUP.

The Expansion group is situated about a mile southwest of Union Pass, at an elevation of 3,200 to 3,600 feet. It is owned by the Expansion Gold Mining Company, of Kingman, which acquired the property in October, 1905, and has operated it since April, 1906.

The property comprises six or more claims, situated along the contact zone. It is crossed near its middle point by a prominent gulch that heads near the pass and affords good exposures of the relations of the intrusive rocks to the pre-Cambrian granite. The portion to the southeast of the gulch lies along a contact scarp. That to the northwest is located on a prominent hogback. The camp is located on this gulch just above the hogback, and is amply supplied with good well water confined by an andesite dike intruded into the rhyolite.

The developments at the time of visit were a 220-foot tunnel near the crest of the hogback and a crosscut. Since then, however, it is reported that much work has been done and a 60-ton mill has been installed.

There are two lodes on the property. The more westerly is on the contact of the rhyolite porphyry and the pre-Cambrian gneissoid granite. Its silicified zone is about 200 feet wide and is traceable for a considerable distance in a northwesterly direction. It contains bands or belts of ore of varying width. The samples from the surface are stated to have given assays ranging from a few cents up to $90 a ton in gold, and contain also a little silver. The eastern lode is on the

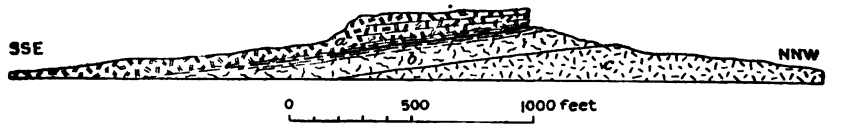


FIGURE 35.—Cross section of part of Tragedy vein. *a*, Rhyolite; *b*, older rhyolite porphyry and quartz; *c*, granite.

contact of andesite and rhyolite. Its surface values range up to $11 a ton, and the mineralization extends laterally a considerable distance into the rhyolite.

In the southeastern part of the property, which was being developed by a tunnel at 100 feet below the croppings of the rhyolite-granite contact on the granite side of the contact, moderate values were reported in the granite. In the older orange-colored altered rhyolite that floors the valley just north of the camp fair gold values are said to occur over an area of 10 acres or more. This rhyolite is in part silicified and vuggy. All the Expansion ore is cyaniding ore.

TRAGEDY GROUP.

The Tragedy group is about 2 miles west-southwest of Union Pass and about a mile southwest of the San Diego group and "mammoth ledge," at an elevation of about 3,200 to 3,400 feet. It was discovered in 1900 and was first worked in 1903. It is owned by W. E. Sauls, O. D. M. Gaddes, and G. B. Ayres, of Kingman. It is located in a detached elongated foothill. A section of the rocks and the deposit is shown in figure 35. The exposures seem to represent the southern

limb of an eroded anticline of rhyolite flows, of which the section at the San Diego and O. K. groups, figure 33, is the northern limb. The structure is monoclinal, with the dip gently to the south.

The capping rhyolite is massive and white, but its lower 3 or 4 feet are streaked reddish. The older rhyolite porphyry is a highly altered reddish-brown iron-stained rock. It contains lime carbonate and much quartz, and in places it completely gives way to quartz. Its upper 3 or 4 feet is silicified and banded parallel with its contact with the rhyolite above.

The vein or ore bed, consisting of quartz and iron-stained altered and silicified rock containing the values, occurs in the upper 30 or 40 feet of the older rhyolite porphyry. The ore may have originally been deposited in this rock, but was probably subsequently enriched by circulation of thermal solutions that attended and followed the eruption of the younger rhyolite.

The developments consist of several tunnels or inclines and shafts driven 30 or 40 feet into this ore bed. Several hundred tons of good milling ore and some ore averaging $76 a ton are reported to have been produced.

UNION PASS GROUP.

The Union Pass group, better known as the Union Pass mine, is located about 3½ miles southwest of Union Pass, about 2 miles from the Tragedy group, and 5 miles east of Colorado River. It is situated on open ground at an elevation of about 2,400 feet, on the Harpers road about one-half mile below its junction with the Union Pass and Pyramid road. It was discovered about 1886 and is owned by the Union Pass Mining Company, of Philadelphia.

It is situated on a lode which follows a great fault plane between the pre-Cambrian country-rock granite on the west or foot-wall side and intrusive and effusive rhyolite on the east or hanging-wall side. The fault strikes N. 30° E. and hades to the east at angles of about 20°. It is normal with the upthrow on the west. The hanging-wall side of the lode is deeply slickensided.

The granite, a coarse porphyritic rock, is sheeted and made schistose along the zone of contact. The rhyolite is mostly agglomeratic and contains many bowlders or bowlder-like masses 2 to 3 feet in diameter. It is cut by a coarse jointing which approximately parallels the fault plane, and by a later sheeting having a southerly dip. Along the planes of the sheeting occur dikes of intrusive andesite and diabase or basalt and thin lentils or tabular bodies of a gray rock, apparently a limestone.

The lode, which in general is about 100 feet or more in width, consists mainly of a tabular body of fault breccia or agglomerate composed of rhyolite, andesite, granite, and quartz, and contains

veins of quartz and adularia, calcite, and silicified rock and lentils or tabular bodies of the gray rock resembling limestone, the latter being about 30 feet in maximum diameter and 7 or 8 feet in maximum thickness. Thin dikes or stringers of a later dark intrusive andesite are also present. The quartz and adularia and spar or calcite favor the hanging-wall or rhyolite side of the lode, and here in association with these minerals the values mostly occur. The croppings consist of brown and dark iron and manganese stained, silicified breccia and quartz, which in places is greatly crushed.

The property is opened at the foot of a fault scarp, rising steeply to a height of about 80 feet, forming the face of low hills on the west and overlooking a broad wash on the east. It is developed by a tunnel 120 feet long, a 100-foot incline winze or shaft, starting at 20 feet in from the mouth of the tunnel, and a 60-foot crosscut extending from the bottom of the shaft to the southeast under the wash. At the time of visit the shaft was said to contain 26 feet of water. It was reported that a 12-stamp mill and a pump were to be immediately installed.

Samples taken across the lode from the entrance to the face of the 100-foot tunnel are said to have given an average assay of about $4 a ton in gold. The best ore, however, occurs at the shaft in a 5-foot tabular vein composed of fairly pure quartz and adularia. It is said to average about $25 in gold to the ton.

To the south of the mine the croppings of the lode are prominent, and are said to continue so for a distance of 2½ miles from the mine, disappearing beneath a wash-covered mesa on the southwest.

A partial cross section of the lode as exposed at a point about one-third of a mile south of the mine, in the face of a prominent chimney-shaped cropping rising 25 or 30 feet high, is as follows:

Partial cross section of Union Pass mine lode exposed in croppings one-third mile south of Union Pass mine.

	Feet.
1. Rhyolite-andesite breccia, containing gold-bearing reddish-stained quartz	20
2. Breccia consisting of coarse bowldery agglomeratic rhyolite, granite, and quartz	15
3. Breccia, less coarse than No. 2, mostly granitoid and limy and containing veins of calcite and quartz with adularia	20
4. Breccia, granitoid, finer than No. 3	15
5. Metamorphosed semicrystalline "limestone"	5
6. Coarse porphyritic granite, country-rock foot wall.	

OTHER PROPERTIES.

Other properties in the district are the Monarch, New Chance, Sunlight, Coleman, Colorado, Miller, and Golden Eagle.

Monarch property.—The Monarch property comprises a group of six claims situated about 3 miles southeast of Union Pass, on or near the crest of the range, on open ground, at elevations of 3,600 to 3,700 feet. It is owned by J. S. Withers and Robert Brannack, of Kingman. It was discovered in 1904. The developments consist mainly of a shaft 60 feet deep, about all in granite.

The property lies just south of the point where the mineralized contact zone extending eastward from the Expansion property reaches the crest of the range and, curving to the south, loses its regularity and unity and is less well defined, portions of it occurring on either side of the crest. The country rock is the pre-Cambrian granite, with the usual intrusive irregularly present.

The shaft is sunk on a lode which seems to be a southward extension of a part of the Mammoth lode. Its upper 30 feet exposes a 10-foot vein composed mostly of quartz and light-colored clayey gouge with altered rock and calcite. It is stained in spots with malachite. The vein dips steeply to the east, with quartz forming the "foot wall," from which it is separated by 5 inches of red clay gouge, and granite forming the hanging wall. The ore is in streaks but a few inches in width, contained in the vein. It is reported to average about $40 in gold and $10 in silver to the ton, and contains a trace of copper. Below a depth of 30 feet, however, though calcite and quartz continue on the hanging-wall side, the vein becomes lean and consists mostly of argillaceous material.

New Chance property.—The New Chance property is located about 4 miles southeast of Union Pass, about a mile south of the Monarch mine, on the upper west slope of the range near the crest, between 3,600 and 3,900 feet in elevation. It was discovered about 1900 and is owned by Mike Redman, of Kingman. The developments are slight.

The general country rock is the pre-Cambrian granite, cut by a sheeting that dips steeply to the north.

The deposits occur in a lode contained in granite, rhyolite, and andesite and are reported to range from 20 to 30 feet in width. The strike is about N. 18° W. To the south of the gulch the lode stands about vertical, but to the north it dips steeply to the west. It is exposed for a horizontal distance of nearly half a mile and through a vertical range of 200 or more feet. The croppings, which are in part prominent, are dark iron and manganese stained quartz and silicified rock, which is chiefly rhyolite.

The ore is mostly contained in a vein about 2 feet thick, composed of quartz, calcitic brecciated rhyolite and andesite, and green fluorite. The ore streak in this vein, as shown in the shaft on the upper or south end of the property, where the vein is in rhyolite, with a greenish porphyritic rock similar to the andesite of the Vivian close by, is 8 to 10 inches in width, and is reported to average about $64 in

gold and 2 ounces of silver to the ton. The values are found mostly in the quartz-adularia portion of the vein, and are said to be best where associated with the fluorspar.

To the north of the gulch the ore, here also contained in a quartz-spar gangue, is fairly well developed along the rhyolite-granite contact, and at a point where the rhyolite is faulted off the ore continues for a distance of 200 feet in an extension of the fissure into the granite.

Sunlight property.—The Sunlight property, owned by J. D. Richardson, of Kingman, is about 1½ miles south of Union Pass and 3 miles west of the New Chance, on open ground, at an elevation of about 3,100 feet. The deposit is a 2½-foot vein of greenish quartz, adularia, and calcite, with some intermingled greenish or brecciated rock, and contains fair gold values. It dips about 60° E. and lies entirely in granite. It is opened by a 53-foot shaft and several smaller excavations. Near the bottom of the shaft the gangue becomes mostly altered granite, of which 1 foot on the hanging-wall side carries from $1 to $5 in gold to the ton, and is separated from the wall rock by several inches of clayey gouge.

PILGRIM DISTRICT.

The Pilgrim district, which is about 2 miles in length and trends northwestward, lies 9 miles west of Chloride, in the eastern foothills of the range, at an elevation of about 3,600 feet. The country rock is principally rhyolite and granite porphyry. The main opening is the Pilgrim mine, on the northwest. It was discovered March, 1904, by two prospectors, Dempsey and O'Dea, of Kingman, who still own it. Soon after it was bonded to Brockman, who developed it. It has a 12-horsepower gasoline hoist. This mine is situated on a contact vein between rhyolite breccia, with trachytic rhyolite, forming the hanging wall and granite porphyry in the foot wall. It is developed by inclined shafts, two levels, and drifts to a depth of 360 feet, and oxidation extends to the bottom of the mine. The vein is about 20 feet thick and about half a mile in length. It dips about 30° W. The gangue consists of quartz, with a little adularia and calcite. The ore is reported to average about $8 in gold to the ton, the gold occurring free. Twelve tons of $100 ore are reported to have been shipped, and about 1,000 tons of what is stated to be $6 to $7 ore lie on the dumps.

VIRGINIA DISTRICT.

The Virginia district, about 3 miles in diameter, lies 25 miles west-northwest of Chloride, near the middle of the west slope of the Black Mountains, 5 miles east of Colorado River and nearly opposite

the Searchlight district, Nevada, at an elevation of about 1,500 feet.

The country rock consists of the Tertiary volcanic rocks, with rhyolite and green chloritic andesite most abundant. The veins dip southwestward, usually have a calcite gangue, and locally grade into the country rock. The Red Gap vein, however, consists of more or less brecciated quartz, probably with adularia. It is similar to that in the Gold Road mine and carries good values.

The ore of the district is mostly free-milling gold. It averages about $7 to $8 a ton, and the best values are associated with specks of hematite distributed throughout the gangue, as in much of the ore in the Union Pass and Gold Road districts.

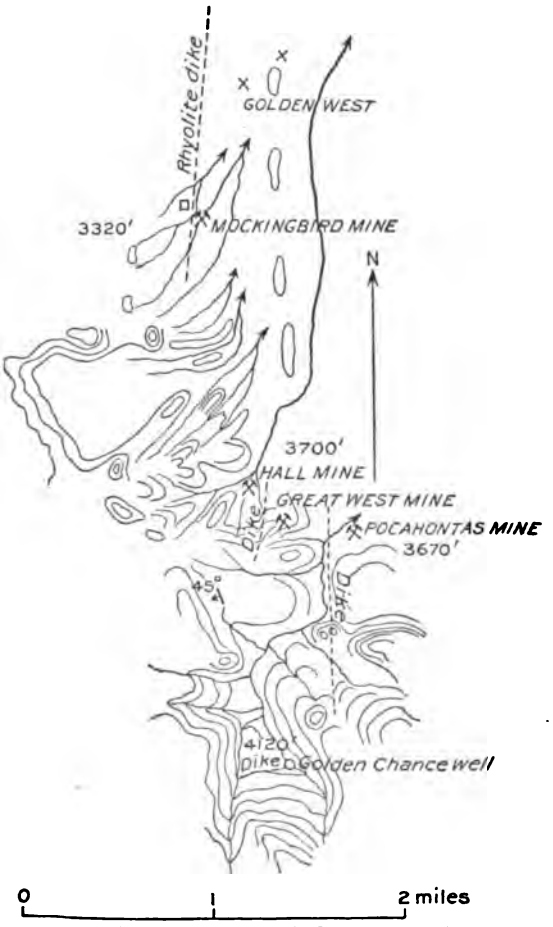


FIGURE 36.—Sketch map of Mocking Bird district.

MOCKING BIRD DISTRICT.

GENERAL OUTLINE.

The Mocking Bird district (fig. 36) lies 25 miles northwest of Chloride, in a reentrant parallel side valley in the east foothills of the range, at elevations between 3,000 and 4,000 feet. The valley is bounded on the east by a spur of volcanic rocks extending in a northerly direction from the flank of the range. The district trends north and south; it has a length of about 5 miles and a width of about 2½ miles. It is hilly on the south but open on the north, merging with the Sacramento Valley, which receives its drainage. Water is scarce, but some is encountered in the mines. The principal mines are the Mocking Bird, Hall, Great West, and Pocahontas. The Mocking Bird and Hall are now producing.

MOCKING BIRD MINE.

The Mocking Bird mine (fig. 37) is situated in the open northern portion of the district. Its principal developments are 12 or 15 shafts, ranging from 25 to 60 feet in depth, and about 500 feet of drifts. The vein lies nearly flat in a local sheet or flat-lying dike of altered and pressed minette, containing secondary epidote, calcite, and adularia. Other volcanic rocks near by consist of rhyolite tuff and latite. The vein is about 6 feet thick and consists of red and green quartz and breccia. The metal is gold with a small amount of silver. The gold occurs in a finely divided state, usually associated with hematite, of which much is present. The ore averages about $10 a ton. The production to date is reported to be more than $20,000; several times this amount of ore is said to be blocked out in the mine.

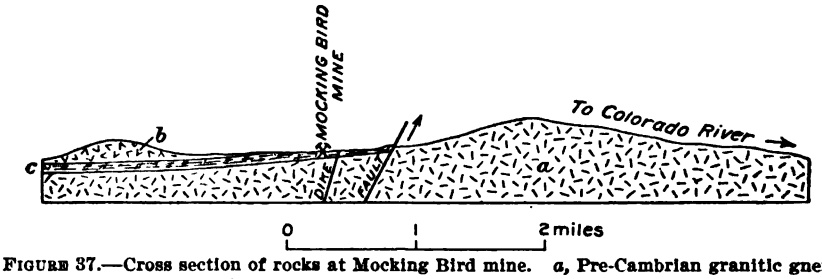


FIGURE 37.—Cross section of rocks at Mocking Bird mine. *a*, Pre-Cambrian granitic gneiss and schist; *b*, trachytic latite and rhyolite; *c*, minette.

HALL MINE.

The remaining mines are situated near together in the low foothills of pre-Cambrian granite in the southern part of the district. The veins here all dip steeply to the north. The Hall mine, which works the most northerly of the veins, is developed principally by a 210-foot shaft and two levels, containing about 200 feet of drifts. The vein ranges in thickness from a few inches to 2 feet, and is locally associated with diabase dikes. The gangue is quartz, some being of the honeycomb variety. Some of the ore is very rich, shows free gold, and is said to contain values of $10,000 or more to the ton. A 24-ton mill is operated at the mine.

GREAT WEST MINE.

The Great West mine is developed principally by adit drifts, shafts, crosscuts, and winzes to a depth of more than 200 feet. The vein is approximately 3 feet thick and consists essentially of gold-bearing, iron-stained oxidized quartz, reported to run from $10 to $80 a ton.

POCAHONTAS MINE.

The Pocahontas mine is developed by a shaft and drifts to a depth of 200 feet, and a new cyanide mill has recently been built to replace

the stamp-amalgamation mill formerly used. The value of the ore is in gold, which occurs mainly in pyrite contained in a somewhat stained and crushed quartz gangue.

GOLD BUG DISTRICT.

The Gold Bug district is situated near the summit of the range, about 3 miles north of the Mocking Bird district, 3 miles south of Eldorado Pass, and 30 miles northwest of Chloride. The only mine is the Gold Bug mine, which is developed by several shafts and drifts to a depth of 300 feet.

The deposits consist chiefly of two main veins situated about 22 feet apart in a doubtful volcanic rock, possibly a minette similar to that at the Mocking Bird mine. The veins dip steeply to the northeast. The ore is rich gold-bearing quartz, with a little silver, and favors the hanging wall, where in part it is associated with a diorite (?) dike. Much ore is said to remain in the mine.

Mr. H. J. Marmein, representing the Gold Bug Mining Company, has kindly given the following historical notes and account of recent development work:

This property consists of several patented claims. The first discovery of gold on these claims was made in 1892 by two Mormon miners, and the exceedingly rich ore taken out at the very beginning of work attracted much attention. In 1893 the property was sold for a large sum and was then worked in a desultory way for two years; during this time about 50 tons of selected ore was shipped, which netted $43,000, or about $860 a ton in car lots, after deducting all transportation and smelter charges. The owner erected a 20-ton Huntington mill on the banks of Colorado River, about 10½ miles from the mine, and 800 tons of the low-grade ore put through this mill, saving only 58 per cent of the assay value, gave returns on the plates of $12,000, or $15 a ton. Owing to lack of capital, the work was discontinued and the mine lay idle until March, 1908, when the present company began working the property.

The old workings consist of 15 shafts and open cuts, about 2,300 feet of underground work all told. The main shaft is now down 300 feet. Two shafts, each about 200 feet distant from the main shaft, on other veins, have been developed to depths of 100 and 140 feet.

As a result of operations of 1908 on the 290-foot level, which seems to be nearing the limit of the oxidized zone, it is reported that for the 70 feet of drift run the vein has an average width of about 5 feet and on either wall contains an ore streak which attains about 18 inches in maximum width. The ore of this streak averages from a few dollars to several hundred dollars in gold and from $1 to $60 in silver to the ton and shows coarse and free gold.

The quartz gangue of the vein is shattered, and the best values occur in its more shattered portions in association with iron oxide in the oxidized zone, and with pyrite and galena and vanadinite at greater depths, where sulphide ore is coming in and the ore bodies and values are becoming more regular.

ELDORADO PASS DISTRICT.

The Eldorado Pass district, an area about 2 miles in diameter, lies west of the White Hills at Eldorado Pass, on the road leading to Eldorado Canyon, at an elevation between 2,500 and 3,000 feet. The topography is one of gentle relief. The country rock is the pre-Cambrian granite, and it is intruded and locally overlain by the Tertiary volcanic rocks. The principal properties are the Burrows, Bagg, Young, and Pauly. They are in the prospect stage, but have produced some gold, the production of the Burrows being reported to be about $10,000. The metals of the three first named are gold and silver in quartz veins; the Pauly, which seems to be at the contact between the granite and the volcanic rock, contains principally copper.

NONMETALLIC MINERAL RESOURCES.

The principal nonmetallic mineral resources occurring in the region here discussed are building stone, cement rock, caliche(?), turquoise, and graphite.

Building stone.—The most important building stone in the region is the rhyolite tuff underlying Kingman Mesa. It occurs in abundance in heavy beds and is easily quarried in the scarps near Kingman. It is medium grained and fairly uniform in texture and dresses well. The most important buildings in Kingman are built of it.

Cement rock.—The main cement material of the region is a fine-grained pumiceous phase of the rhyolite tuff just described. It occurs in a deposit of considerable extent west and southwest of Kingman and probably elsewhere and is said to have been proved by experiment to be excellent for making cement. It requires no calcining. Briquets made with it are reported to have a high tensile strength and to stand salt-water test with excellent results.

It is also very probable that excellent materials for cement, brick, lime, and building-stone purposes occur abundantly in the Carboniferous and other Paleozoic limestones and shales of the Grand Wash Cliffs region, which, so far as learned, have not yet been exploited for these materials. The Carboniferous, which is strong here, has, as is well known, long been supplying these materials in enormous quantities for the above purposes throughout the Middle West, as well as in other sections of the country.

Caliche (?).—Calcareous deposits locally called "limestone" and "travertine" and used as flux at the smelters occur in Sacramento Valley, near Chloride, Mineral Park, and elsewhere. The deposits in place were not visited by the writer, but to judge from quarried material from them piled at the old smelter near the Chloride depot, where it had been used as flux, the deposits seem undoubtedly to belong to the class of subsurface calcareous deposits known to have a wide distribution in the hot, arid plains of Arizona and adjoining regions in the Southwest, and described by various authors under the names "caliche," "subterranean travertine," "tepetate," "tierra blanca," etc. In mineralogical, structural, textural, and other characteristics the material corresponds very closely with that described by Blake,[a] and in hand specimen it was readily identified by Dr. T. W. Vaughan, who is experienced with deposits of this class,[b] as being in all probability caliche.

The caliche deposits in the Southwest usually occur in more or less continuous sheets from 1 foot to 15 feet in thickness underlying the surface soil. They are formed not by hot springs, but by precipitation and concentration of calcareous material, through the evaporation of subsurface lime-bearing waters, which may be ascending, descending, or both, depending mainly on local climatic conditions.

Turquoise.—Turquoise is actively mined by several companies near Mineral Park, notably at Ithaca Peak, about 1½ miles to the southeast, and Aztec Mountain, about 3 miles to the south. It occurs in coarse altered granite porphyry in the form of veins and globular and irregular bodies, 1 to 8 inches in diameter, some of which are connected by stringers or mere seams and others isolated in the solid rock. The production is mostly shipped in monthly installments to New York, where it is sold chiefly in the rough for jewelry purposes.

A fuller account of the deposits, by Douglas B. Sterrett, is being published in the Mineral Resources of the United States for 1908.

Graphite.—Graphite, possibly of commercial value, occurs in the pre-Cambrian schists on the east slope of the Cerbat Range near the old government trail in Canyon Station Wash, a few miles southeast of Mineral Park.

Amethyst.—In the McConnico district, in a mineralized zone in the pre-Cambrian rocks, about half a mile north-northeast of Boulder Spring, amethysts have been found, one of which is reported to have been sold to the Tiffany Company for $59. The property is developed by several shafts, of which the deepest is about 65 feet deep.

[a] Blake, Wm. P., The caliche of southern Arizona; an example of deposition by vadose circulation: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 220–226.

[b] Vaughan, T. W., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1898, p. 256.

WATER SUPPLY.

Throughout that portion of the area which lies north of the latitude of Kingman water is scarce, the only natural source of supply besides precipitation being a few small springs, found along the base of the ranges. In the pre-Cambrian rocks, however, particularly in the Cerbat Range, as shown in the mines, ample water of good quality is usually encountered at depths of 300 to 600 feet; and in the vicinity of Kingman in the rhyolite tuff a copious supply is reached at depths of about 130 feet, as shown by numerous wells. In the Black Mountains the best water-bearing formation is the rhyolite tuff, commonly known as the "water rock," extending in a belt of considerable width from Union Pass southward beyond Gold Road. It is the source of water used at Gold Road and other localities, and, as at Kingman, the supply seems inexhaustible. Water occurs in about all the shafts in the Gold Road and Vivian districts that are 200 feet or more deep.

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O

Bulletin 397

J C Branner

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 398

GEOLOGY AND OIL RESOURCES

OF THE

COALINGA DISTRICT

CALIFORNIA

BY

RALPH ARNOLD AND ROBERT ANDERSON

WITH A REPORT ON THE

CHEMICAL AND PHYSICAL PROPERTIES OF THE OILS

BY

IRVING C. ALLEN

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GEOLOGY AND OIL RESOURCES OF THE COALINGA DISTRICT, CALIFORNIA.

By RALPH ARNOLD and ROBERT ANDERSON.

INTRODUCTION.

GENERAL.

The Coalinga oil district occupies a strip of land about 50 miles in length by 15 miles in width along the northeastern base of the Diablo Range, on the southwest side of the San Joaquin Valley, in western Fresno and Kings counties in central California. The region is accessible by rail from the main lines of both the Southern Pacific and the Atchison, Topeka and Santa Fe railroads by a branch line of the Southern Pacific running westerly from Goshen to Coalinga. The proved productive oil territory is comprised in a band 13 miles long by 3 miles wide in the foothills in the northern end of the district, within the Coalinga field proper, together with a narrow strip along the district's southwestern boundary in the Kreyenhagen field.

The rocks of this region are chiefly marine sedimentary strata of Cretaceous and Tertiary age. These have been subjected to much disturbance, but are in large part only slightly consolidated. There are two types of oil, a paraffin oil which appears to have originated in foraminiferal shales in the Upper Cretaceous, and an asphalt oil which is believed to have its original source in diatomaceous and foraminiferal shales of upper Eocene age. The former is accumulated in sandy zones interbedded with the shales that are supposed to have given rise to it; the latter, which is the chief product of the district, is accumulated to some extent in the Tejon formation, but chiefly in sands of the Vaqueros (lower Miocene), Santa Margarita(?) (upper middle Miocene), and Jacalitos (upper Miocene) formations. The Vaqueros is the principal producer of the district. The oil wells vary in depth from 600 to over 4,000 feet and penetrate from 20 to over 200 feet of productive sands. The product varies from a black oil of 14° or 15° Baumé to a greenish oil of 35° Baumé or better. The yield ranges from 3 or 4 barrels per day for individual wells in the Oil City field to as much as 3,000 barrels per day for the deeper holes in

the Eastside fold. The total production for the district in 1907 was 8,871,723 barrels, in 1908, 10,386,168 barrels, and it has probably reached over 15,200,000 barrels in 1909. It ranks first among the districts of the State in production.

The location of the Coalinga district and of the other oil districts of southern California is shown in figure 1.

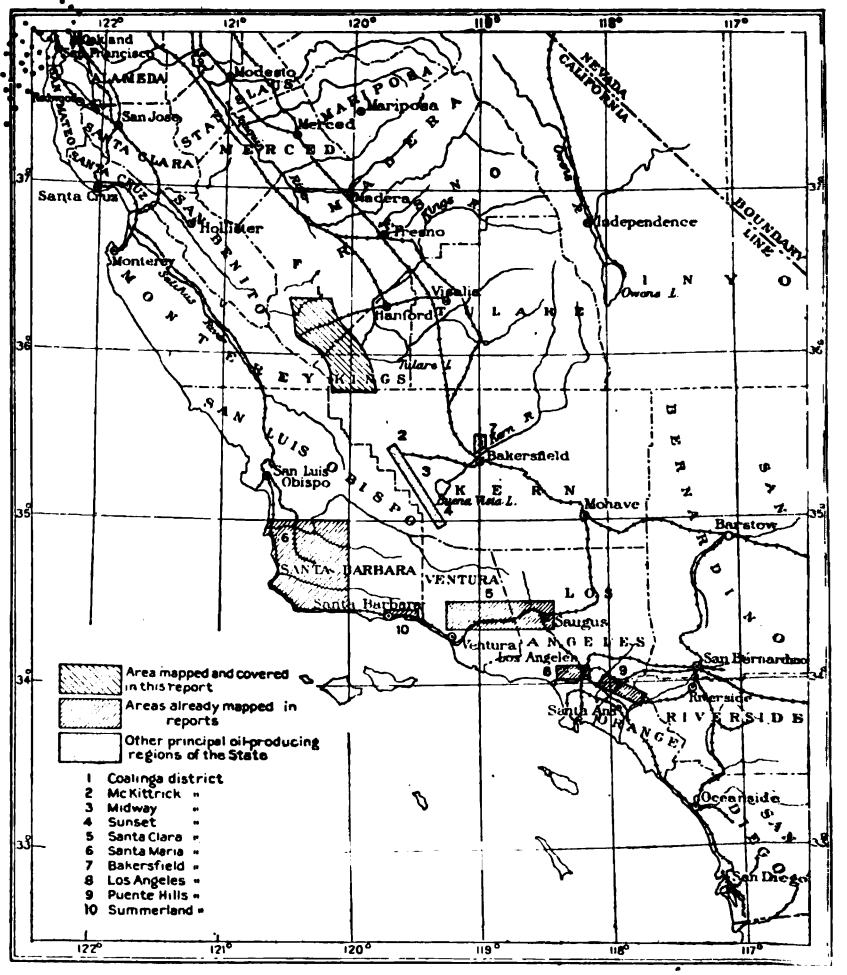

FIGURE 1.—Index map showing position of the Coalinga district in central California.

PLAN OF THE PRESENT WORK.

The purpose of this report is to treat of the general topography, geology, paleontology, and occurrence of petroleum in the Coalinga district, special importance being given in the discussion of the geology to those features bearing a direct relation to the problems of present and future development of the oil resources of the region.

The work is a continuation of the investigation of the California oil fields that is being carried on by the United States Geological Survey. During the last half of 1901 and the first half of 1902 George H. Eldridge began this investigation and made more or less detailed examinations of the various California oil districts, with the expectation of preparing a monograph on them. Upon his return from field work he wrote a brief résumé of the results obtained, and this was published in "Contributions to economic geology for 1902."[a] Later he began the preparation of detailed reports on each field, but unfortunately his death in June, 1905, cut short this work. In the fall of 1905 the senior author of the present report was assigned to the completion of the work begun by Mr. Eldridge, and by the middle of 1907 detailed reports on all of the oil districts in the counties bordering the coast had been made ready for the press.[b]

The summer and fall of 1907 were spent by the writers in making a detailed geologic investigation of the Coalinga field proper and of the territory south of it as far as the line between Kings County and Kern County, near Dudley, and a reconnaissance of the surrounding regions. In order to make the economic results of this investigation available as soon as possible a preliminary report containing a portion of the matter here presented was published in the autumn of 1908.[c]

The present report includes a more complete discussion of the topography, geology, and paleontology, and gains in value by the addition of maps, sections, and other illustrations, and in particular by the addition of the paper on the physical properties of the oils prepared by Irving C. Allen. The preliminary report may be considered as superseded by the present one.

In explanation of the plan of this and the other geologic reports bearing upon the California oil fields, it must be stated that these publications are intended to be as thoroughly scientific discussions as possible within the limitations of time available for their preparation, and they assume upon the part of the reader a general knowledge of the fundamental facts and conceptions upon which any searching study of the composition, mineral deposits, and history of

[a] Eldridge, George H., The petroleum fields of California: Contributions to economic geology for 1902, Bull. U. S. Geol. Survey No. 213, 1903, pp. 306-321. (That part relating particularly to the Coalinga district is on pp. 306-308.)

[b] The editions of these reports that were issued for free distribution are entirely exhausted. They are as follows:

Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills and Los Angeles oil districts, southern California: Bull. U. S. Geol. Survey No. 309, 1907, xi+266 pp., 17 figs., 41 pls.

Arnold, Ralph, and Anderson, Robert, Preliminary report on the Santa Maria oil district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 317, 1907, 69 pp., 1 fig., 2 pls.

Arnold, Ralph, Geology and oil resources of the Summerland district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 321, 1907, 93 pp., 3 figs., 17 pls.

Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 322, 1908, 161 pp., 26 pls.

[c] Bull. U. S. Geol. Survey No. 357, 1908, 142 pp., 1 fig., 2 pls.

the earth must be based. The reports may be criticised as being too technical and as not easily comprehensible by the ordinary reader; but the form of discussion adopted is the only possible method of presentation because the treatment involves a certain amount of technical knowledge and the use of exact terms. For explanations of the principles of geology or the meaning of terms the reader is referred to any one of the numerous text-books of geology.[a]

ACKNOWLEDGMENTS.

The writers wish to acknowledge their indebtedness to the late George H. Eldridge for the use of the notes collected by him during his examination of the field. Acknowledgment is also due to other previous workers in the field, among whom are W. L. Watts, Frank M. Anderson, John H. Means, and H. R. Johnson. This paper benefits by the inclusion of chemical analyses of rocks furnished by W. F. Hillebrand and R. C. Wells, of the United States Geological Survey, and of a discussion of the petrographic character of the syenite from White Creek, by E. S. Larsen, jr., also of the Survey. S. G. Mason aided in the preparation of the fossil tables.

The economic value of a report like the present one, including as it does a discussion of the geology of developed territory, depends largely upon the amount and accuracy of the well data available for use in its preparation. Certain facts may be gleaned from a critical examination of the surface outcrops in any field, and many helpful conclusions may be deduced from a study of the facts thus obtained; also a comparison of the conditions met in a given territory with those in other better-known fields is often of great assistance; but for furnishing specific information regarding the occurrence of the oil in any particular area there is just one instrument, and that is the drill.

From the drilling of wells in the Coalinga field during the last ten years a large body of useful data concerning the underground conditions has been accumulated, and whatever of accuracy and value there is in the underground map and statements concerning the geology of the wells in this report is due almost entirely to the generosity of the operators in this field in supplying the information. The writers therefore wish to acknowledge their indebtedness to the officers, managers, and other operators of the different oil companies for their hearty cooperation and support. Thanks are due more particularly to Messrs. James H. Pierce, W. W. Orcutt, S. A. Guiberson, jr., R. W. Dallas, W. R. Hamilton, A. and H. Kreyenhagen, R. S. Peeler, A. M. Anderson, H. G. Anderson, J. M. Atwell, Charles Babtie, Gordon M. Baker, R. C. Baker, Orlando Barton, H. J. Bender, Scott Blair, S. R. Bowen, F. S. Brack, H. H. Brix, C. A. Canfield,

[a] Any of the following, besides various others, will be found useful: Dana, Text-book of geology; LeConte, Elements of geology; Chamberlin and Salisbury, Geology (3 parts); Geikie, Text-book of geology.

Frank Cleary, H. R. Crozier, F. P. Dagany, P. B. Daubenspeck, D. M. De Long, J. F. Ecbert, Andrew Ferguson, A. D. Ferguson, W. S. Fisher, A. D. Fram, Charles Fredeman, W. A. Gray, W. A. Greer, L. P. Guiberson, H. D. Guthrey, S. H. Hain, H. H. Hart, Thomas Hayes, R. S. Hazeltine, H. Henshaw, W. A. Hersey, Paul Huntsch, W. A. Irwin, W. N. Kerr, W. P. Kerr, J. E. Kibele, Besley Lafever, J. L. Lennon, Walter Lewin, M. E. Lombardi, E. W. Mason, W. G. McCutcheon, R. P. McLaughlin, W. O. Miles, J. H. Miller, S. E. Mills, R. B. Moran, T. A. O'Donnell, P. F. Page, Z. L. Phelps, J. H. Raney, Charles V. Reynolds, George D. Roberts, J. M. Robertson, C. N. Root, Guy H. Salisbury, George Schwinn, H. N. Seavers, Max Shaffrath, R. E. Shore, R. H. Smith, H. F. Stranahan, R. E. Thompson, T. H. Turner, P. S. Turnbull, J. Waley, J. L. D. Walp, Alex Wark, J. H. Webb, M. L. Woy, J. B. Wrenn, John M. Wright, and many others who have contributed in one way or another to the value of the report.

The writers also wish to express their gratitude to Mr. R. B. Marshall, geographer in charge, and to Mr. E. P. Davis, topographer, for hearty cooperation during the course of the field season, when the topographic and geologic work were progressing simultaneously.

ADVANTAGE OF COOPERATION AMONG OPERATORS.

The Coalinga oil field will continue to be the greatest in California if every operator will conserve to the utmost the supply of oil stored within the boundaries of the district, and by wise management aid in keeping it available. An approximation of the amount of available oil in the territory covered by the underground-contour map (Pl. XV) is 2,737,000,000 barrels. (See under the heading "Production," p. 247.) Some persons have the idea that underground resources of any kind are inexhaustible, but the notion is erroneous. When the oil in any field is once exhausted it will not be replaced within the limits of many centuries, if ever. It is not impossible that the processes of oil formation and migration are taking place constantly in some places, but such processes are so exceedingly slow when measured in years that they may be considered for practical purposes as nonexistent.

Fortunately the Coalinga field has had little of the serious trouble with water that is ruining certain parts of some of the other fields of California. This lack of trouble is probably due largely to the little-disturbed condition and the uniformity of the oil-bearing formations over most of the territory. But trouble from water is beginning to show its effects in certain parts of the field, and in more than one instance wells not yet abandoned are believed to be, either through accident or carelessness, letting water into sands that are productive in not far distant wells. In order to avoid the dangers incident to faulty drilling and handling of wells, the operators should meet and exchange

information about the underground geology. It seems shortsighted for one operator to withhold his logs and other information about underground conditions from his neighbor, when this very withholding may be the cause of his neighbor's flooding a large area through lack of proper knowledge in shutting off the water. Furthermore, it is hoped that the legislature will recognize the needs of the petroleum interests in California, and, as has been done in other States, provide laws protecting the producers from negligent, shortsighted, or criminally careless methods.

PREVIOUS KNOWLEDGE OF THE GEOLOGY.

The mountains and plain along the western border of the interior valley of California have not received much attention from scientific investigators, owing to their isolation, the sparseness of the population, and the difficulties of travel. In recent years, however, the exploitation of its mineral resources has called attention to the region, and a small body of literature containing information of various kinds regarding it is gradually growing up. The early surveys of portions of California that were made in connection with the explorations for a railroad route to the Pacific Ocean by a number of engineers and scientists under the direction of the United States War Department, and in connection with the State Geological Survey under J. D. Whitney, did not include the region of the Coalinga district, so that until recent years little was known directly concerning its geology or physical features.

The State Geological Survey party carried its geologic reconnaissance no farther south in the Diablo Range than the region of the New Idria quicksilver mine, which is about 25 miles northwest of Coalinga, but some general references to the topographic aspect of the more southerly mountains were made in the report published by Whitney and are quoted below in the discussion of place names. In 1888 the United States Geological Survey published a report by G. F. Becker [a] on the quicksilver deposits of the Pacific slope, which contains a chapter on the geology of the New Idria region. The features of that region are in many respects similar to those along the Diablo Range farther south.

The occurrence of coal, quicksilver, oil seepages, and gypsum in the region of the Coalinga district and the hope of finding other mineral deposits led a number of persons to prospect there in the early years, and the amount of investigation of this kind that has been conducted has increased more recently, with the result that an extremely productive oil region has been discovered and developed. But the first systematic geologic investigations that are known

[a] Mon. U. S. Geol. Survey, vol. 13, 1888.

to have been carried on were those of W. L. Watts, who examined the oil fields along the border of the central valley of California for the California State Mining Bureau, and published a report on them in 1894.[a] The report contains valuable information concerning the geology of particular areas and gives a general outline of the succession of the geologic formations, the ages of which were determined roughly with the aid of paleontologic identifications by J. G. Cooper. The material of this report is reviewed in a later publication by the same writer.[b]

In 1894 J. G. Cooper published a paper in which he describes the fresh-water fossils collected by Watts in the region of the Kettleman Hills, west of Tulare Lake.[c]

In the course of his investigations of the geology of the California oil fields George H. Eldridge, of the United States Geological Survey, spent much labor in studying out the intricacies of the geologic formations along the eastern flank of the Diablo Range, but unfortunately his death left the work uncompleted. A brief review of his knowledge of the petroleum fields of the State, in which he outlined some of the main facts in the geology of the Coalinga field and adjoining regions, appeared in 1903.[d]

Up to 1905 the notes published on the physical features of the Coalinga district had been scattering, but in that year Frank M. Anderson, who had been led by his interest in the oil fields and in California geology in general to take up a study of this region, published a paper[e] in which a comprehensive review of the geology and paleontology of the Coalinga district and neighboring regions is given. The paper has been of considerable service to the present writers and frequent reference to it will be noted in the text.

Shortly before the appearance of the authors' preliminary report (Bull. 357) Frank M. Anderson issued a paper[f] supplementing the one just mentioned and offering a revision of some of his first conclusions regarding the age of what he called the "Coalinga beds" and "Monterey shale." A brief summary of the principal paragraphs in his first paper is also given, this being made advisable by the destruction of the California Academy's stock of that paper during the fire of April, 1906.

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[a] The gas and petroleum yielding formations of the central valley of California: California State Min. Bureau, Bull. 3, 1894.

[b] Oil and gas yielding formations of California: California State Min. Bureau, Bull. 19, 1900.

[c] On some Pliocene fresh-water fossils of California: Proc. California Acad. Sci., 2d ser., vol. 4, pt. 1, 1894, p. 166.

[d] Contributions to economic geology for 1902: Bull. U. S. Geol. Survey No. 213, 1903, pp. 306–321.

[e] A stratigraphic study in the Mount Diablo Range, California: Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 156–206, with plates.

[f] A further stratigraphic study in the Mount Diablo Range of California: Proc. California Acad. Sci., 4th ser., vol. 3, 1908, pp. 1–40.

Owing to the rapid development of the oil resources of the Coalinga district and the demand for information regarding the region, a preliminary report, containing the major portion of the data of direct importance to the problems of oil occurrence that have been collected by the present writers, was published in November, 1908, as Bulletin 357 of the United States Geological Survey. A brief paper dealing with a portion of the district describes the occurrence of recently formed conglomerate on White Creek.[a]

Paleontology has played a prominent part in the working out of the various problems, both scientific and economic, connected with the Coalinga district, and in order to present this branch of geology more fully a bulletin entitled "Paleontology of the Coalinga district, Fresno and Kings counties, California," was prepared by the senior author and has just been issued as Bulletin 396 of the United States Geological Survey.

GEOGRAPHY AND TOPOGRAPHY.

DEFINITION OF PLACE NAMES.

For the sake of accuracy and convenience of reference a proper understanding must be reached regarding the names of the various places and features in the Coalinga district before a proper topographic and geologic description can be given. The region is one in which little detailed investigation has been made, and most of the natural features are unnamed, while to many others names are indefinitely applied. In the following pages are definitions of names that have been newly applied and names whose application has been made more definite. Almost all these names, including all the more important ones, have been submitted to the United States Geographic Board and have been approved and made permanent by that body. Most of these names appear on the map accompanying this report.

Coalinga district.—The application of this name to the whole region included in the map accompanying this report is discussed on page 25.

Coalinga field.—The term "field" has been adopted as representing a subdivision of a "district," and the name "Coalinga field" is used in this report in its accepted sense as meaning the region of the developed oil field in the northern portion of the territory mapped, round about Pleasant Valley, in which Coalinga is situated. This region is in turn subdivided into the Eastside, the Westside, and the Oil City fields, terms which are in common usage and will be defined in the discussion of the developed territory.

Kreyenhagen field.—Similarly the region of the hills west of Kettleman Plain is referred to as the Kreyenhagen field.

[a] Conglomerate formed by a mineral-laden stream in California, by Ralph Arnold and Robert Anderson: Bull. Geol. Soc. America, vol. 19, 1908, pp. 147–154.

Kettleman Hills field.—The possible future oil field east of the Kettleman Plain will be referred to as the Kettleman Hills field.

Diablo Range.—The Diablo Range is the easternmost member of the California Coast Ranges south of San Francisco Bay. It extends southeastward from Carquinez Straits along the western border of the San Joaquin Valley. The name is taken from Mount Diablo, a prominent peak 15 miles southeast of Martinez on the Carquinez Straits, and heretofore has been variously used for the small group of mountains centering around this peak, or for a part or all of the group of mountains extending southeastward from there and limiting the central valley of California on the west. The United States Geographic Board has fixed the southern limit of the range at Antelope Valley in the northwest part of Kern County just south of the region mapped as the Coalinga district, and has determined that the correct name is "Diablo Range," instead of "Mount Diablo," "Monte Diablo," or "Sierra del Monte Diablo." The range is considered as terminating at this valley because it there sinks into low spurs, and the continuation of the mountain belt beyond the valley is a markedly individual range that is en échelon with the southernmost spur of the mountains to the north. This spur bringing the Diablo Range to an end is the one dividing Antelope and McLure valleys, later referred to as Avenal Ridge. San Benito River separates the Diablo and Gabilan ranges farther north, but in the latitude of the Coalinga district the two ranges, owing to a complication of structures, coalesce into a high mountainous tract in which various component members run at angles oblique to the main trend of the Coast Ranges. In the portion south of the headwaters of San Benito River and Los Gatos Creek, the range may be considered as extending clear across to the drainage basin of Salinas River. In his chapter on the "Monte Diablo Range" [a] J. D. Whitney devotes the opening paragraph to a definition of the range. He says:

> In its northern extension the Monte Diablo Range is easily defined; but to the south it widens and inosculates with other ranges, or spurs, falling into it from the northwest, until finally, uniting with the extreme western members of the great group of the Coast Ranges, it forms the broad region of high rolling hills, intersected by a labyrinth of narrow valleys, which lies between the parallels of 35° and 35° 30′ and where distinctness of nomenclature for the different groups of elevations is almost entirely lost. For convenience, and as representing as nearly as possible a natural division of the Coast Ranges, the Monte Diablo Range may be considered as terminating to the south in the low ridges running out into the San Joaquin Plain at the head of Los Gatos Creek, in latitude 36° 20′.

Elsewhere,[b] however, Whitney does not adhere to this limitation of the range, and describes as its most southerly division the mountains lying to the south between the "Estrella Pass," by which

[a] Geol. Survey California, Geology, vol. 1, 1865, p. 8.
[b] Idem, pp. 9–10.

he means the divide at the head of Los Gatos Creek, and the "Roble Pass," by which he means some divide across the range opposite the town of Paso Robles, most probably the pass now known as the Polonio Pass, which is at the head of Antelope Valley and which is here adopted as the southern termination of the Diablo Range. Whitney divided the range into several divisions, of which the above-mentioned division is the southernmost. He named it the "Estrella division," the group of mountains next to the north of it, between the head of Los Gatos Creek and the Panoche Pass, being named by him the "San Carlos division."

The explorations of the Geological Survey of California in the Diablo Range did not extend farther south than the region of the New Idria quicksilver mines, and therefore the knowledge obtained by them of the mountains to the south was not extensive. This is indicated by Whitney's impression, stated in the paragraph above quoted, that the southern continuation of the Diablo Range united with the westernmost members of the Coast Ranges between latitudes 35° and 35° 30′. As a matter of fact, the easternmost division of the Coast Ranges is isolated along most of this portion of its course, and may more properly be said to unite with the westernmost mountains south of latitude 35°. Other points in his description of the mountains are correct, however, and point to the appropriateness of including the "Estrella division" as a part of the Diablo Range. He characterizes the divide between the head of Los Gatos Creek and the San Benito River as "not a low one," and states that the "Estrella division" to the south of this is of considerably less elevation than the "San Carlos division," and that it "sinks very low as we approach Paso Roble." The divide at the head of Los Gatos Creek is, in fact, high and does not form a pronounced break in the range, whereas the mountains do sink low in the McLure, Antelope, and Cholame valleys, at the south end of the group named by Whitney the "Estrella division." It is therefore in harmony with Whitney's description of the Diablo Range, as well as with the features of the relief, to consider the range as terminating in the region of Antelope Valley.

Temblor Range.—Southeast of Antelope Valley a range of distinct topographic and structural individuality forms the divide between the San Joaquin Valley on the northeast and the basin of San Juan Creek and the Carrizo Plain, on the southwest. It extends from Cholame Creek on the north to about latitude 35°, where it merges with the high mountain mass around Mount Pinos called the "Tejon Mountains." To this range the name "Temblor" is here applied.

The topographic and structural separation of this range from the Diablo Range is definitely marked on the north by Antelope Valley, but its northeastern termination must be more arbitrarily assigned. It may be considered as ending at Cholame, or as continuing to the

northwest across the canyon of Cholame Creek and following the western side of Cholame Valley to some point northwest of Parkfield. It seems more appropriate to consider it as so continuing and finally terminating gradually in the inclined plateau that slopes to Salinas River. The name Temblor is particularly suited to the range for two reasons: First, because the great California fault line, along which earthquakes have repeatedly originated, follows the range from one end to the other, being in the very heart of it throughout its northern part. A pronounced scarp and trough resulting from recent movements can be traced all along this line. Second, because the well-known old Temblor ranch, west of McKittrick, is situated on its flanks.

Joaquin Ridge.—A very prominent structural ridge runs southeast from the high mountains south of Idria to the San Joaquin Valley north of Coalinga, forming the divide between Los Gatos Creek on the south and the tributaries of Salt Creek and Cantua Creek that run northeastward to the San Joaquin Valley. The ridge forks in its upper part, one branch heading in a mountain nearly 5,000 feet high situated in the northwest corner of the area mapped, and the other to the north, in the high region of San Benito Mountain. The summit of the ridge is serrated with picturesque rocks, one striking group of which is locally known as the "Joaquin Rocks." The name Joaquin Ridge is here applied to the ridge.

Anticline Ridge.—The oil field north of Coalinga is on the nose of Joaquin Ridge, and immediately southeast of the main portion of the field is a depression in the ridge. Southeast of this point, which is in the southern part of sec. 34, T. 19 S., R. 15 E., a low, broad line of hills extends about 6 miles to the railroad line in the gap formed by Los Gatos Creek. (See Pl. XV.) This ridge is formed by a perfect anticlinal nose, and is therefore referred to as "Anticline Ridge."

Juniper Ridge.—A ridge approximately parallel with Juniper Ridge runs south of Los Gatos Creek from the divide between that stream and Lewis Creek as far as the canyon of Waltham Creek (Alcalde Canyon). It is a high, rugged ridge dividing the important Waltham Valley depression on the southwest from the Los Gatos Creek depression on the northeast and the low hills between Los Gatos and Waltham creeks (Alcalde Hills) on the east. This ridge is cut abruptly by Waltham Creek, south of which it is continued for about 2 miles in the isolated ridge known as "Curry Mountain." It is here called "Juniper Ridge" owing to its characteristic vegetation.

Castle Mountain.—The name Castle Mountain has heretofore been indefinitely applied to a part or all of a high, sharp ridge at the headwaters of Zapato, Canoas, and Big Tar creeks, which is visible from the valley on the east as the summit of the Diablo Range. The ridge is a very definite natural feature, presenting an abrupt escarp-

ment to the northeast, and forms the western boundary of the southern corner of Fresno County. It extends from about the head of Zapato Creek to a point south of the head of Avenal Creek. The name may well be used for the whole ridge. This name has not been passed upon by the United States Geographic Board.

Avenal Ridge.—The name Avenal Ridge is here applied to the mountains separating Avenal Creek and McLure Valley from the Cholame and Antelope valleys. It is the southernmost of the spurs of the Diablo Range. The name, which means a "field of oats," is appropriate, because the hills forming the ridge are rounded and grass-grown, and afford a flourishing annual growth of volunteer oats. (See Pls. IX, *A*, and XI, *A*.)

Reef Ridge.—A prominent ridge faces the low hills that border Kettleman Plain, running southeast, between Castle Mountain and the foothills, from the south fork of Jacalitos Creek (Jasper Canyon) as far as Little Tar Canyon north of Dudley. A steep escarpment follows the northeast flank of this ridge, being formed by the prominent lower Miocene fossiliferous strata termed the "reef beds," which dip at a high angle and owing to their resistance rise high above the softer sand hills on the northeast. The name Reef Ridge, which is indicative of the most prominent one of its topographic features and of an important element of its geologic structure, is here applied to this ridge. (See Pl. VIII.)

Alcalde Hills.—The foothills between Los Gatos and Waltham creeks, east of Juniper Ridge, northwest of Alcalde and west of Coalinga, are here called the Alcalde Hills.

Jacalitos Hills.—The foothills between Waltham and Jacalitos creeks are here given the name Jacalitos Hills. Xacalli is an Aztec word adopted by the Mexicans, meaning "Indian hut" or "wigwam," and Jacalitos means "the little wigwams." The origin of this name is not known, but an observer can not fail to see in the symmetrical conical knolls a resemblance to tents or wigwams from which the name might have sprung. This descriptive suggestion makes the name particularly applicable to these hills. (See Pl. II, *B*.)

Kreyenhagen Hills.—The foothills southeast of Jacalitos Creek, between Reef Ridge and Kettleman Plain, may be named Kreyenhagen Hills. (See Pl. II, *A*.) The name is that of three families owning large tracts of land there. They are early settlers and almost the only inhabitants, and the region is generally known as the "Kreyenhagen country" or "Kreyenhagen's," or the "Kreyenhagen field." The last name is used in this report for the oil field of the vicinity.

Pyramid Hills.—A long, narrow line of hills borders the eastern side of McLure Valley, extending from Little Tar Canyon, about 3 miles north of Dudley, to the Dagany Gap, where the Avenal flows

out of the valley, about 4 miles south of Dudley. South of this gap they continue into the Devils Den region. They form a ridge capped with a succession of conical hills, which when viewed from the east appear like isolated and similar pyramids. They are therefore here called the Pyramid Hills.

Tent Hills.—A somewhat similar line of hills of peculiar topographic and geologic structure extends along the Avenal at the northeast foot of the high ridge (Avenal Ridge) west of McLure Valley. They begin about 4 miles west of Dudley and run 3½ miles northwest, being separated from Avenal Ridge by a marked depression. Owing to the resemblance of the individual hills to tents they are here called the Tent Hills. (See Pl. XI, *A*.)

Guijarral Hills.—Immediately southeast of Anticline Ridge, on the opposite side of the railroad, is a small low group of gravelly hills referred to in the text under the designation Guijarral. This is a Spanish word meaning "a heap of pebbles" or "a place abounding in pebbles."

Dagany Gap.—The name Dagany Gap is used for the gap at the lower end of McLure Valley, south of Dudley, through which Avenal Creek takes its outlet. It is named from an old settler of that region.

Avenal Gap.—The Kettleman Hills are cut at latitude 35° 50′ by a completely graded stream channel that is now followed by Avenal Creek. It will be referred to in the text as Avenal Gap.

Polvadero Gap.—At their north end the Kettleman Hills are separated from the Guijarral Hills by a plain which is the drainage course of Zapato, Canoas, and Garza creeks. It is called Polvadero Gap because subject to dust storms. Certain of the early land maps have it "Pulvero," but this is not correct.

Pleasant Valley.—At least a portion of the valley at the mouth of Los Gatos Creek has been known as Pleasant Valley, the usage not being definite. The name may well be applied to the whole basin in which Coalinga is situated.

Waltham Valley and Creek, and Alcalde Canyon.—The creek at the mouth of which Alcalde is situated is variously known as "Wartham," "Warthan," "Waltham," and "Alcalde." The United States Geographic Board has decided that Waltham is the correct name. This stream heads in a broad structural valley having no relationship in geologic character with the lower portion of the stream course. (See Pl. V, *A*.) The name Waltham Valley already in use for this upper valley should be definitely restricted to that part and not applied to the valley of the lower portion of the stream. It seems advisable to distinguish the canyon formed by Waltham Creek along its lower course under the name Alcalde Canyon, thus preserving a name which is already understood as referring only to the lower part.

This name is therefore applied to the canyon extending from the edge of Waltham Valley, where the stream cuts between Juniper Ridge and Curry Mountain, to Pleasant Valley.

McLure Valley.—The valley in which Dudley is situated has long been known as McLure Valley, after an early settler, now dead. According to old inhabitants, that is the original and proper name. It is, however, widely known as "Sunflower Valley" by reason of the abundant growth of wild sunflowers. The United States Geographic Board has decided that the former is the correct usage. (See Pl. XI, *A*.)

Kettleman Hills and Plain.—The United States Geographic Board has decided that these names are properly written with an "e" and should not be spelled "Kittleman."

Various creeks and canyons.—The Geographic Board has considered the various usages in regard to the names of the creeks in the Coalinga district, and the results of its decisions appear on the map.

For convenience of reference the present authors have applied names to the various marked canyons in the district. The canyon that runs north and south 7 to 10 miles due north of Coalinga, which is followed by the road to Oil City, is named Oil Canyon. (See Pl. III.) The canyon in the Alcalde Hills which runs southeasterly across secs. 2, 11, 12, and 13, T. 21 S., R. 14 E., and which throughout its course across secs. 2, 11, and 12 is practically coincident with an anticline, is called Anticline Canyon. The application of the name Alcalde Canyon has been made above. The south fork of Jacalitos Creek may be appropriately named Jasper Creek, from the picturesque and brilliantly colored buttes of jasper that surround its upper portion. The name Jasper Canyon is therefore applied to the gorge that this stream forms across the northwest end of Reef Ridge. The sharp canyon cut through Reef Ridge by Zapato Creek is called Zapato Canyon, and the similar one, formed through Reef Ridge by the south fork of Zapato Creek, 2 miles farther east, may be named Sulphur Spring Canyon from the abundance of sulphur water that issues in it. The similar canyon at the head of Canoas Creek is called Canoas Canyon. The names Big Tar Canyon and Little Tar Canyon are in common usage for the features to which these names are applied on the map.

Laval grade.—The Laval grade is a name locally known for the road leading northeastward up a branch of Oil Canyon, starting in that canyon on the east side of the NW. ¼ sec. 29 and crossing the ridge at the head of this branch canyon in the center of the NW. ¼ sec. 21, T. 19 S., R. 15 E. This name will be frequently used for reference.

Dudley-Lemoore road.—The good road crossing the Kettleman ills about 4 miles north of Avenal Gap will be referred to as the udley-Lemoore road.

LOCATION.

The region here mapped and referred to as the Coalinga district situated in the southern part of Fresno County and the western art of Kings County, Cal., and is bounded on the south by the Kern ounty line. It forms a long strip of territory extending from 119°)′ west longitude and 35° 47′ north latitude at its southeast end to 20° 37′ west longitude and 36° 20′ north latitude at its northwest nd, along the foot of the Diablo Range. This is the easternmost ember of the Coast Ranges, on the border of the Great Valley of alifornia. The district as mapped is roughly 50 miles long and 15 iles wide and extends over about 700 square miles. It covers the othill belt along the valley and extends back into the high hills to ie summits of the first surrounding mountain ridges, its northwest nd southwest corners reaching the crest of the Diablo Range.

The developed oil territory commonly referred to as the Coalinga eld is in the northern part of the district, in the foothill region round Pleasant Valley, where the town of Coalinga is situated. This the only important settlement in the district or in the large sur- ounding region, the country being very sparsely inhabited. The ames Oil City, Alcalde, and Dudley, which are marked on the map nd often referred to in the text as if they represented places of impor- ance, derive their chief importance from the scarcity of place names in ie region and the necessity of having points of reference. Oil City merely an area in which an oil camp is situated and in which evelopment took place in an early part of the history of the field, lcalde is the terminus of the Coalinga branch of the Southern Pacific ailroad near a farmhouse a few miles southwest of Coalinga, and)udley is a stage station and post-office in McLure Valley. Oilfields a post-office recently established in the field north of Coalinga.

The branch railroad mentioned joins Coalinga with the main lines f the Southern Pacific and Atchison, Topeka and Santa Fe railroads n the San Joaquin Valley, and wagon roads enter the district at everal points from the valley on the east. Roads cross the Diablo ange from the west in the latitude of this district at four points—(1) ver the Benito Pass at the head of Los Gatos Creek, (2) over the livide between Priest Valley and the head of Waltham Creek, (3) cross the range between Stone Canyon and Waltham Creek, and (4) ver Cottonwood Pass. The first enters the Coalinga district along Los Gatos Creek, the second and third along Waltham Creek, and the fourth down Avenal Creek and McLure Valley.

CLIMATE, DRAINAGE, AND VEGETATION.

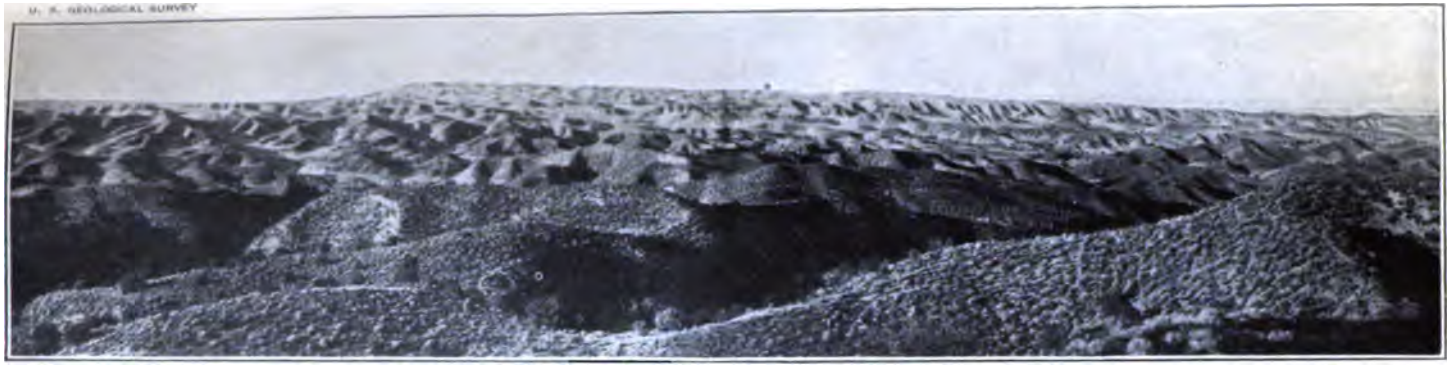
The climate in the region of foothills and plain along the western border of the San Joaquin Valley is arid. The rainfall is almost entirely limited to the "rainy season," chiefly from November to March, and is then slight. During the summer the days are hot and the atmosphere dry, the region becomes desiccated, and the streams dwindle and cease to flow on the surface before reaching the valley. They continue, however, to have an underground flow and the plains thus receive underground much of the drainage of the Diablo Range. Water is obtainable in wells at most places in the district, but it is generally poor. Large quantities of it are pumped from beneath the plain at various points and it is likewise found abundant at various depths in the oil wells drilled in the hills. Owing to the large original content of salts of various kinds in the formations, and the aridity of the climate, which allows this material to remain on and near the surface, the waters of the region are usually highly mineralized. Almost all water used for drinking purposes is brought by train from farther out in the San Joaquin Valley.

The vegetation, as shown in the landscape views accompanying the text, is very sparse. The large plain and lower hills are naturally treeless and are overgrown with herbaceous and shrubby perennial vegetation, in most places scantily, as illustrated particularly by Plates II, *A* and *B*, III, and XVIII. The higher hills and the narrower valleys have in addition to such vegetation a scattering growth of small trees, principally oaks and junipers, as illustrated in Plates XVIII, IX, *A*, and XI, *B*. The mountain slopes are dotted with numerous, although rarely thickly set pine, juniper, and oak trees and present an attractive background to the valley border region. Some of the trees attain a good size and are locally used on a small scale for lumber. The growth on the higher slopes as shown in Plate XVIII is fairly typical of the mountainous region. The character of the underlying rocks exerts a marked influence on the vegetation, and belts occupied by different formations or lithologic zones may frequently be traced by the abundance or sparseness or character of the plants.

RELIEF.

GENERAL TOPOGRAPHIC FEATURES.

The Coalinga district owes its broader topographic features to its position along the border between the Coast Ranges and the interior valley of California. It is largely a region of foothills that rise on the west into the mountains and merge on the east with the wide level plain. The plain stretches thence with unbroken sweep to the foot of the high wall of the Sierra Nevada, the snowy summit of which is



A. ARID FOOTHILL BELT OF TERTIARY FORMATIONS.

Looking northeast from Zapato Creek across Kreyenhagen Hills toward the valley. Photograph by Ralph Arnold.

B. MONOCLINE OF TERTIARY STRATA IN JACALITOS HILLS.

Looking north from Jacalitos Creek, along the strike of the beds on the left, and across the strike on the right. Photograph by Robert Anderson.

quently part of the landscape in the early morning or during the ole of clear days. The foothills form a continuous belt, in places rrow but more commonly miles in width, along the base of the ountains, but are arranged in several groups along the base and ound the ends of spurs descending southeastward from the Diablo ange, the groups being separated from each other by reentrant val- ys that open out to the San Joaquin Valley.

Viewed from a distance across the dry, treeless plain the moun- ainous belt of the Diablo Range appears as a continuous, fairly even- opped ridge, covered with scattering vegetation and therefore blue n color, set back behind a broad belt of lighter-colored, grass-grown oothills that seem to form an inclined terrace sloping up gently ward the mountains. From nearer at hand broad valleys appear closed within outlying foothill spurs, the near-by hills assume great ominence and are seen to be sharply dissected, deep canyons appear ithin the mountainous belt, and the horizon line is observed to be rmed not by one continuous mountain ridge but by a series of dis- ntinuous overlapping ridges running into the range toward the rthwest at angles slightly oblique to the general direction followed y the edge of the valley and the range as a whole.

The area included in the accompanying map is not a well-rounded opographic province. None of the larger stream courses are shown ore than in part, and the area is bounded not by the main crest of the ountains but by overlapping sections of the outlying high ridges at face the valley.

Some of the prominent features of the landscape have been out- ined and briefly described in the preceding discussion of place names.

DIABLO RANGE.

General features.—The Diablo Range in the latitude of the Coa- ga district is a broad mountain group of moderate general profile t locally rugged character forming a continuous barrier 2,500 to ,000 feet in height and 30 to 40 miles broad between the San Joaquin alley on the northeast and the San Benito, Salinas, and Cholame alleys on the west and southwest.

The summit altitudes of the crests of the range decline from the region rth of Los Gatos Creek in the San Carlos division toward the south the Estrella division (these names being those applied by the Geo- gical Survey of California under Whitney, as before mentioned), until ally declining along Avenal Ridge toward McLure and Antelope alleys, where the range comes to a stop and gives place on the south- st to the Temblor Range. Portions of the main watershed appear on the accompanying map at only two points—in the northwest rner, which is marked by a peak nearly 5,000 feet in height that nds at the head of Joaquin Ridge, and in the southwest corner,

where the much lower Avenal Ridge, the southernmost spur of th range, appears. In the intermediate region the ridges that are repre sented on the western edge of the area are in general separated fro the main divide farther west by a region of lower relief determine by the presence of oblique structural valleys, of which Waltham Va ley is the principal one.

Distinction from foothills.—The mountainous region within the Co linga district is marked off topographically from the foothill regio both by its higher altitudes and steeper slopes, which in many case begin abruptly along a line at the margin of the foothill belt, and b its somewhat different type of topographic development. The tw regions are geologically distinct, for the reason that the mountai tract is one almost entirely of older and harder rocks, and the fo hills mark the belt of softer Tertiary and Quaternary formations. In some portions of the region, however, a line of separation betwee the foothills and features more properly called "mountains" is no naturally traced.

Outcrops and slopes.—The mountainous region affords abundant out crops. It owes its topographic distinction from the foothill belt largely to the superior hardness of its constituent rocks, which stand out on ridge tops and canyon sides with bold relief. As examples may be cited the remarkable exposures of the sandstone strata on the flanks of Joaquin Ridge, along the face of Reef Ridge (see Pl. VIII), and on the escarpment of Castle Mountain. The ridges are usually fairly even topped, and have gentle summit slopes descending toward the larger drainage lines that follow the lines of structure and toward the val ley; their flanks where cut by erosion have steep sides that drop abruptly into V-shaped transverse canyons. Steep slopes also border the broader structural valleys as effects of the structure—for exam ple, the southwest face of Juniper Ridge and Curry Mountain (Pl. V, *A*) and the northeast face of Castle Mountain, which are prob ably due to faulting, and the steep dip scarp of Reef Ridge (Pl. VIII). As suggested above, the lines of drainage are principally of two kinds those paralleling the structural lines and directly consequent upon the structure, which are the main lines, and those transverse to the struc ture, which are more strictly erosional in origin and are the principa lines of sharp dissection. These second lines of drainage have smal tributary courses due to erosion that run either parallel with or obliqu to the strike of the beds, and likewise cut deeply, exposing dip slopes and strike faces.

Constituent ridges.—A peculiar feature of the Diablo Range, which has already been suggested, is the presence along its eastern flanks of numerous spurs running out toward the southeast and of reentrant valleys between these spurs. These ridges and valleys trend a little more nearly east and west than the range as a whole, which trend

about N. 35° to 40° W. They are primarily due to structural causes and not to erosion. The main salients of the Diablo Range that project toward the San Joaquin Valley in the Coalinga district are Joaquin Ridge and its structural continuation in Anticline Ridge and the Kettleman Hills, Juniper Ridge and Curry Mountain, Reef Ridge, the mountain northwest of McLure Valley, between the drainage of Big Tar Canyon and Avenal Creek, which forms the southern extension of Castle Mountain, and Avenal Ridge. These, as well as the valleys or depressions separating them, are the topographic expression of folds and faults running obliquely to the main trend of the Diablo Range. These constituent ridges, which were mentioned under the subject of place names, will be described individually in the following paragraphs.

Joaquin Ridge.—Joaquin Ridge is anticlinal and exposes on its lower flanks the oil-bearing formations, thus determining the position of the oil field north of Coalinga. The ridge is structurally continued by the Kettleman Hills, which form a prominent isolated group rising over a thousand feet above the San Joaquin Valley. The spur formed by Joaquin Ridge and the Kettleman Hills is separated from the rest of the district by the synclinal and faulted depression of White and Los Gatos creeks and the synclinal Pleasant Valley and Kettleman Plain.

The ridge has a narrow but rounded crest that descends gradually from an altitude of nearly 5,000 feet in the northwest corner of the district toward the east and southeast, and then declines more steeply toward the head of Oil Canyon and the high foothills on which the Eastside oil field is situated. From a distance the summit appears smooth except for occasional notches and the sawtooth appearance presented by the outcrops of strata that dip down the ridge. One group of these outcrops forms the picturesque towers known as the Joaquin Rocks. On either side the ridge sends out long, smooth-topped, but steep-sided lateral ridges that decline by gentle stages toward the adjacent main lines of drainage and toward the valley. These ridges are separated by deeply trenched canyons transverse to the strike of the strata.

Toward its head Joaquin Ridge has a different topographic character, due to the different nature of the rocks. It assumes the gentle outlines everywhere characteristic of the areas occupied by the serpentine associated with the Franciscan formation. The flank extending down to White Creek appears like an inclined plain notched by widely separated shallow troughs. This portion of the ridge is made visible from a long distance by the white deposits of serpentine lying on the surface, and from near at hand it is seen to be covered over great

areas by bare piles of white, yellow, gray, and brownish-red comminuted serpentine.

The length of Joaquin Ridge is nearly 20 miles and the extent of its flanks from side to side, roughly speaking, 10 or 12 miles.

Juniper Ridge and Curry Mountain.—Juniper Ridge and Curry Mountain form the next spur to the southeast, beyond the Los Gatos Creek and Pleasant Valley depression, belonging together as a continuous structural feature due in part to faulting on the southwest side and in part to the hard strata that strike along it and form the summit (Pl. V, *A*). Within the district this feature has a length of about 14 miles, and it extends much farther northwest. It gradually declines in altitude from elevations of about 4,000 feet at the northwest end to 2,400 feet on the summit of Curry Mountain. The sharp gap of Alcalde Canyon, which begins at the point shown in Plate V, *A*, divides the spur into the two portions named. In the southeastern portion of its extent this spur presents a steep scarp on the southwest side, where it bounds Waltham Valley, and on the northeast a gradual monoclinal slope into the Alcalde Hills. The end of Curry Mountain drops abruptly into a depressed area of low, rolling hills (the Jacalitos Hills) that is the continuation southeastward of the Waltham Valley depression.

Reef Ridge.—Beyond the low area last mentioned a prominent salient springs up along Jacalitos Creek and extends for about 23 miles southeastward as a high divide between the foothills bordering the Kettleman Plain and a belt of low relief, not shown on the map, in which Jacalitos, Zapato, Canoas, and Big Tar creeks head. This divide is Reef Ridge, and all the streams named, as well as their forks, cut sharp gorges through it to a depth of 800 to 1,200 feet. The cliffs on its northeast face and some of the minor canyons crossing it are well shown in Plate VIII. The ridge has a general monoclinal structure, the component strata dipping steeply northeastward as a general rule. The ridge is due in part to the strike of the hard strata and in part to faulting along the southwest side. At its southeastern extremity it gives place to the minor ridge of the Pyramid Hills, which is en échelon with it.

The summit of Reef Ridge rises with smooth but fairly sharp crest from the northwest end toward the central portion, but there breaks into a belt of salient peaks and ridges, some of which rise considerably over 3,000 feet above sea level between the deep canyons that cut across the ridge and the branch canyons that follow along the strike of the softer zones. At the southeast end the ridge narrows into a single sharp crest with even summit and declines gradually to an elevation of less than 1,000 feet. The northeast flank of Reef Ridge is formed by the steeply tilted hard "reef beds" of the Vaqueros

lower Miocene) sandstone, as shown in Plate VIII. Its slope reflects the high angles of the strata and forms a wall against which the comparatively low foothill belt stands in marked contrast. The canyons that are deeply cut at short intervals down the northeast flank of the ridge or completely across it have carved the reef beds into a row of serrate peaks, and parallel zones of hard beds in the Eocene and Cretaceous formations below are similarly although less prominently affected. From near and far Reef Ridge is a picturesque feature of the landscape, and from each changing view point it assumes a different striking aspect.

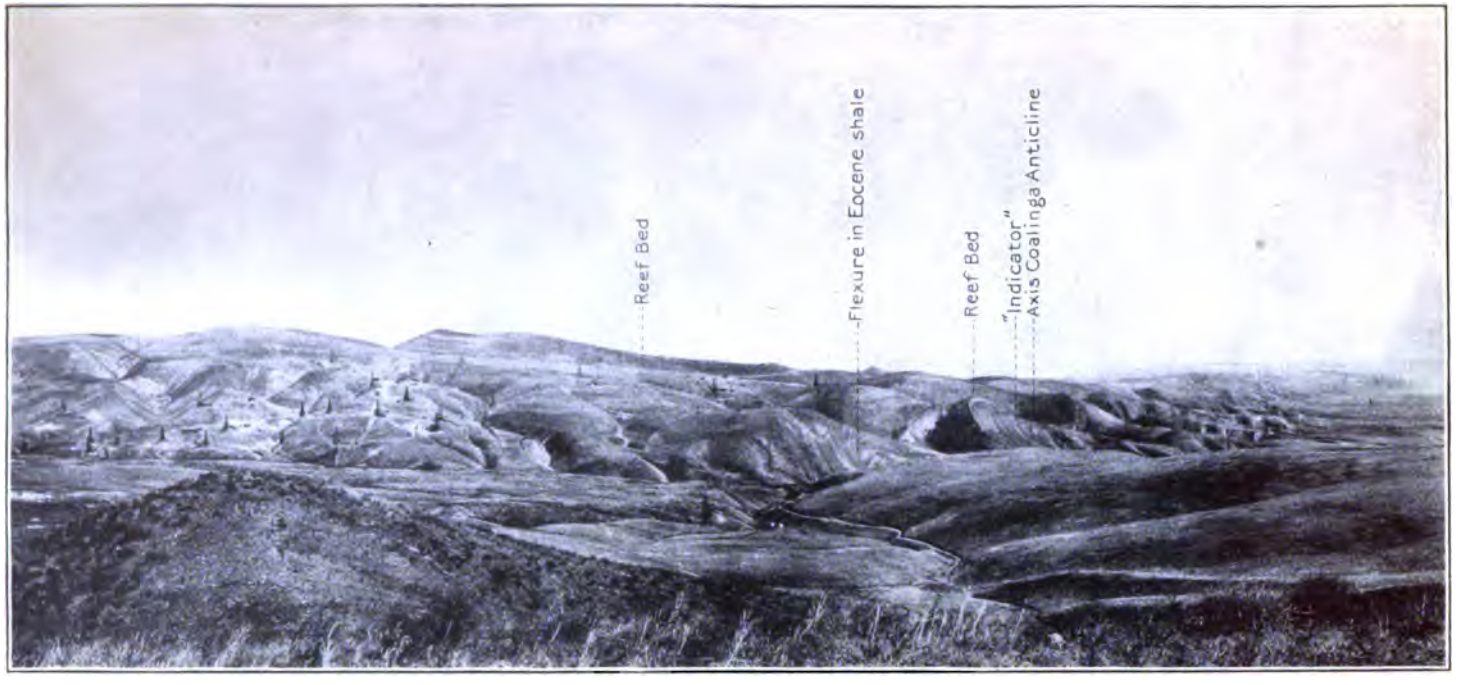
Castle Mountain.—The next salient of importance entering the area of the map is south of the head of Big Tar Canyon and the Castle Mountain fault zone. It is a high and prominent group of hills forming the southeastward continuation of the precipitous ridge of Castle Mountain. Castle Mountain itself is visible from almost all parts of the district as a high, sharp ridge with long, fairly even sky line and abrupt eastern face. It parallels Reef Ridge on the southwest and does not enter the area mapped. The hill group that continues the general line of relief toward the southwest juts out toward McLure Valley as a conically shaped mass reaching a height of over 2,500 feet and sloping away at a medium angle on the north, east, south, and southwest. Around about its base there is a peculiar double row of hills and concentrically arranged depressions that give the group a unique appearance. These features are due to the geologic structure of the spur, which, broadly speaking, is domelike, and to the curving strike around its base of the hard zones that have become weathered and eroded into relief.

Avenal Ridge.—Reef Ridge and the last-mentioned spur are separated from the next salient to the south, Avenal Ridge, by the wide plain of McLure Valley and by the valley of Avenal Creek. Avenal Ridge is the main divide of the Diablo Range. Its extent within the district is less than 9 miles, but it continues beyond, northwestward. It is formed by an important closely folded anticline that plunges steeply southeastward and brings the range to an end. It is a high, bare ridge with gently curving contours and broadly spaced features. It has a fairly even sky line at altitudes between 2,000 and 2,700 feet, which is continuous except for three or four canyon notches. The northeast flank of the ridge descends with fairly steep slope to the foothills, at an elevation of about 1,000 feet, within 1 to a little over 2 miles, but the slope is broken, and locally lessened and steepened, by benches that are due to the prominent relief of hard zones of strata forming longitudinal ridges and lines of hills. These benches are especially evident when seen in profile view, as in Plates IX, *A*, and XI, *A*.

THE FOOTHILLS.

GENERAL DESCRIPTION.

The foothills represent the eroded surface of the upturned Tertiary and early Quaternary formations along the edge of the valley. They form a belt, usually several miles wide, of rolling bare hills following the curving strike of the formations around the projecting ends of the mountain spurs and along the border of the intervening valleys. In the Guijarral and Kettleman hills they assume the character of isolated groups entirely disconnected from the mountainous tracts around which those groups more properly called the foothills, form a fringe. A general similarity of elevation is characteristic of the foothill areas, and comparatively slight relative relief is the usual rule, the summits generally reaching higher and higher altitudes by degrees toward the mountainous belt. The majority of the summits range in altitude between 1,000 and 1,700 feet above sea, or usually between 400 and 1,100 feet above the neighboring valley surface, although a number of massive hills standing out above the general elevation or ridges rising toward the mountains reach as great a height as 2,100 feet. The hills gradually decline in general elevation toward the southern end of the district. The summits of the individual hills and ridges in the foothills belt appear to determine roughly a general plane that slopes upward gently toward the mountains and toward the major ridges, which coincide with the major axes of uplift, and to represent an old surface of erosional planation. This summit plane is in places sharply incised by narrow canyons that have left as much as half the original surface fairly intact or at least not greatly degraded. Instances of this are many in the northern part of the district. (See Pls. III, VII, *A*, and XIII, *A*.) Elsewhere remnants of the general summit are left only at isolated points, as is more commonly the case in the southern part of the district. (See Pl. II, *A* and *B*.) The soft formations of which the hills are largely composed lend themselves to minute, rapid, and fairly uniform sculpturing, which gives the hills the appearance of a wrinkled surface, especially when the obliquely falling rays of the sun have brought out the intricate scattering of light and shade. The hills owe their form chiefly to three causes—to the general reflection, on the surface, of the folds to which their uplift is due; to erosion along lines directed down the slope toward the valleys, at right angles to the structural lines, as a result of which a series of lateral ridges is formed; and to erosion along structural lines, particularly along bedding planes and lines of contact, as a result of which parallel longitudinal ridges and valleys and rows of hills are formed, and the lateral ridges are deformed or dissected into hills. Further detailed sculpturing is due to erosional wash along small channels tributary



OIL CITY FIELD AND RIDGE OF THE COALINGA ANTICLINE.

Looking east across Oil Canyon at hills of Cretaceous and Tertiary oil-bearing formations. Note gently dipping beds on left, overturned anticline in center, and steeply dipping beds along edge of Pleasant Valley on right. Photograph by G. H. Eldridge.

and at right angles or oblique to the streams determined by these two main directions of erosion.

The gently sloping surfaces of the hills are ordinarily smooth, covered with soil or sand, and overgrown sparsely with herbaceous vegetation, sagebrush, and other low plants. The underlying formations form much of the surface, however, especially on the steeper slopes, and although the individual outcrops are not always in prominent relief the appearance of the strata on the surface and their effect on the topography is one of the most striking features of the hills. This effect is chiefly in evidence where differential erosion has brought out certain beds or rapid dissection has left lateral bluffs or steep strike faces of hills exposed. Typical effects of this sort are illustrated by Plates X and XVII. Where the soft formations are traversed by hard zones or beds the latter stand out as hills by virtue of the protection against erosion that they afford to the associated beds, as may be noted in the hills shown in Plates VII, *A*, and XVII. The structure and stratification are in places both broadly and in detail reflected in the degree of relief, the slopes, and the vegetation of the hills. The gravelly and sandy beds, owing to their superior power of absorbing water and possibly also to other conditions, support vegetation where the clay beds do not, and the degree of coarseness of the beds is frequently to be made out by the varying abundance of vegetation, and by variable kinds as well. The result is a marked parallelism and alternation of belts and lines of vegetation. Plates VII, *A*, and XIII, *A*, give a good illustration of the sharp lines of bedding that are brought out by the plant growth, but in most other places the belts follow broader zones.

The foothills of the Coalinga district may be divided into several different groups according to their form, position, degree of distinctness from the mountains, and stage of degradation, although they all present similarities and each group merges in topographic character into the others. The hills toward the northern end of the district partake more of the character of the mountains than those to the south, whereas the latter are much more worn. The following descriptions of these groups will bring out some of their distinctive features.

HILLS NORTH AND SOUTH OF LOS GATOS CREEK.

The relief in the area of Cretaceous rocks northwest of Pleasant Valley partakes of the character of both the mountainous and the foothill belts, and owes its distinctive features to this intermediate position. The region is one of long, high, narrow ridges running out at right angles to the structural lines, from the main ridges to the north and south which parallel these lines. The component strata dip down the ridges and tend to produce angular forms. They also

show their influence in giving rise to lateral extensions of the ridges and to high hills appearing along certain zones on successive ridges: and the manner in which the topography and the outcrops display the curving strike of the strata is remarkable. The ridges are separated by sharp V-shaped canyons at the bottoms of which the stream courses wind back and forth with short sharp turns. The summits exhibit a marked flattening and mutual equality in elevation, especially in the central portion of the Los Gatos Creek drainage basin.

A region of rolling hills carved in the filling of Tertiary deposits opens out toward the upper portion of White Creek, the relief here resembling somewhat that characteristic of the Waltham Valley.

HILLS AROUND THE END OF JOAQUIN RIDGE.

The hills north of Pleasant Valley are the continuation of those farther west and resemble them in that they are primarily formed by prominent ridges extending out from the higher tracts, across the strike of the beds. The ridges here, however, are more broken into individual hills, have broader and more rounded outlines, and reflect the strong influence of the formations and structural lines in spurs that extend out on either side along resistant zones, in hills formed by prominent beds, and in contact valleys. The ridges are thus made irregular and in their higher portions may be said to be rugged, as, for instance, those in the Eastside field shown in Plate XVII. A peculiar feature of these ridges is the irregular crest line which results from the appearance at short intervals of eminences due to the outcrop of hard beds. The knolls so formed present steep slopes or bluffs up the ridge on the strike face and smooth dip slopes down the ridge. Such bluffs are especially numerous on the east flank of Joaquin Ridge. (See Pl. X.) Long canyons that come down out of the higher hills between sharp slopes and with steep gradient gradually open out and become almost lost between the low tongues that reach out toward the valley. .

The longest of the ridges is Anticline Ridge, the extension of the anticlinal dome of Joaquin Ridge. It is a low, broad, even-topped line of elevation with shallow sweeping concavities due to erosion, and slopes gradually toward the gap formed by Los Gatos Creek. Southeast of that gap the same area of relief is continued in the Guijarral Hills. These present an abrupt slope where cut by the gap, but on the summit resume the gradual slope of the surface of Anticline Ridge, forming an inclined plain toward the southwest and south and finally merging with Pleasant Valley and the floor of Polvadero Gap.

ALCALDE HILLS.

South of the gap in the foothills formed by the debouchure of Los Gatos Creek upon Pleasant Valley the valley is bordered by hills that rise more sharply than those on other sides, the slope toward the valley

being a dip slope but little less in angle than that of the beds. The same factors that are of importance in determining the form of the hills before mentioned, namely, the course of the drainage across the line of strike of the strata and the tendency of the strata to form lines of relief paralleling the structure, are here important, but the latter factor begins to assume the greater importance, and the Alcalde Hills are formed largely, especially in their southern part, by longitudinal ridges, gulches, and lines of hills. The southern portion of these hills appears like an inclined plane sloping down toward Alcalde Canyon on the south and up to Juniper Ridge on the west, and intricately and irregularly dissected by long, shallow canyons and steep gullies that trend in general down the slope of the plane, the drainage of the hills being chiefly toward Waltham Creek. Nowhere are the planed summits of the hills more clearly observable than in the steeply inclined plateau-like surface that stretches northwest from Alcalde Canyon up to the flat-topped ridges on the flank of Juniper Ridge.

JACALITOS AND KREYENHAGEN HILLS.

South of Waltham Creek the Jacalitos Hills continue the Alcalde Hills. A difference in character is noticeable, due to more advanced dissection, a more pronounced development of the features reflecting the structure of the strata, and a more distinct differentiation from the mountains. The change increases farther toward the south. The foothill belt from Waltham Creek south is not so apparently a continuous area of relief as in the north, but is composed of fragments of strike ridges separated by broad, smoothly concave longitudinal ravines. These features are illustrated in Plate II, *B*.

The Jacalitos Hills present an abrupt face toward Waltham Creek on the north side of a hill 1,900 feet high southeast of Alcalde, but from the summit of that hill and its spurs the hills decline gradually toward Jacalitos Creek on the southeast and the valley on the east. The drainage is predominantly toward Jacalitos Creek. On the west these hills extend widely and join the rolling area in the region of the Waltham Valley depression and the gentle, irregularly gullied slope of the serpentine area that extends behind Reef Ridge up toward the main crest of the Diablo Range. A prominent feature of the latter area is the group of picturesque buttes of jasper which are scattered over it and which are colored a brilliant vermilion by the growth of lichen.

The Kreyenhagen Hills (Pl. II, *A*) form a long foothill belt following the course of the soft formations between Reef Ridge and Kettleman Plain and are divided into several groups, each a few miles in extent, by streams crossing them at right angles. They abut upon the steep face of Reef Ridge, as shown in Plate VIII, and are distinctly sepa-

rable from the mountainous belt which begins there. To the northeast the strata form ridge after ridge, paralleling each other, and extending the length of the separate divisions between the main stream valleys. These ridges, where regular, may be compared to a series of waves advancing, as on a smooth beach, toward Reef Ridge as the shore, and elsewhere to broken waves, as in a choppy sea. The ridges are slightly asymmetric, the northeast flank being a dip slope and fairly smooth, while the southwest flank is a steeper, strike face that is in many places eroded so as to leave sharp gullies and conical intermediate ridges extending outward. The groups of hillocks so produced bear some resemblance to an encampment of tents or wigwams, and, as elsewhere suggested, the name Jacalitos, meaning the little wigwams, may have been applied to the creek owing to this feature of the hills through which it flows. The greatest symmetry of the parallel ridges appears in the portion of the Kreyenhagen Hills between Jacalitos Creek and Big Tar Canyon, and there the long, straight, smooth troughs between the ridges doubtless gave rise to the name Canoas, meaning canoes, applied to the creek passing across the central portion of the hills.

Toward the south the Kreyenhagen Hills become more and more worn, decline in elevation, and lose their relief. The prominent individual features are absent, and the foothill area is a rolling surface with low sweeping ridges and broad drains sloping gradually toward and merging imperceptibly with the Kettleman Plain.

In the northern group of the Kreyenhagen Hills, as in the Jacalitos Hills, the locus of points of greatest elevation is asymmetric in position, the slope toward Jacalitos Creek on the northwest being steeper and shorter than that toward Zapato Creek on the southeast. The major part of the drainage flows in the latter direction. In the groups of hills between the other streams farther south such a feature is not so clearly to be made out, but it is true that the course taken by the drainage is predominantly toward the southeast.

KETTLEMAN HILLS.

The Kettleman Hills form a small isolated range 30 miles long and 5 to 6 miles broad, about 700 feet above the Kettleman Plain and 1,100 feet above the San Joaquin Valley, extending from northwest to southeast and describing a broad curve toward the south in the southern half. The most striking features of the group are its isolated position in the midst of the surrounding plain, its long, narrow, regular extent, its almost horizontal summit line, which slopes gradually downward toward the two ends, its crescent shape, and its anticlinal origin. The topography is peculiar, and though in some ways similar to that of the hills in other parts of the district has various distinguishing features.

As a result of the difference of elevation of the plains at the foot of the hills on the two sides the flanks are of different topographic character. The crest of the range is not in a central position, but considerably nearer the western side, and is formed by resistant zones of strata. The slope toward the Kettleman Plain is trenched by many sharp gulches, which with their tributary gullies give a minute sculpture to the soft hills. In consequence of the direct course of the drainage toward the valley the ridges are of the transverse type. The eastern flank is of greater extent, is, in general, more worn away, and has more broadly developed topographic features. The drainage lines running to the valley are fewer in number, but of greater importance, and are more like the main streams crossing the Kreyenhagen Hills. The result, as in that case, is the development of tributary streams between strike ridges, these ridges assuming considerable prominence where supported by resistant strata. The flanks of the hills on the two sides and the gently declining elevations toward the two ends appear to determine smooth surfaces sloping away from the crest of the hills. These surfaces are broken, however, by almost level benches that are cut into them, especially at the foot of the main ridge on either side and over most of the eastern flank in the southern half of the hills. Toward the south end, as in the Kreyenhagen Hills, the range is much worn and the relief becomes obscure.

HILLS AROUND M'LURE VALLEY.

The most prominent foothills around McLure Valley are those of the Pyramid Hills type, formed of the siliceous shale of the Santa Margarita (?) formation. This shale is very hard and resistant and stands out as a zone of relief along its outcrop as a result of differential erosion. McLure Valley is surrounded by a fringe of hills produced by this shale, the Pyramid Hills on the east, the Tent Hills on the west, and a prominent wall of knobs circling the base of the mountain spur on the north. As the names given to these hills imply, they are of conical shape. They form continuous ridges, along the summit of which symmetrical cones are left between the heads of the gullies. (See Pls. IX, *A*, and XI, *A*.)

The hills at the head of McLure Valley between these lines of shale hills are very similar to those in the southeastern portion of the Kreyenhagen Hills. They are low and sweeping and merge with the valley floor. Prominent hills or buttes left by differential erosion occur here and there, and a belt of hills thus formed by a hard sandstone zone may be traced in front of the shale hill ridges. A terraced surface of the McLure Valley hills is well shown in Plate XI, *A*.

THE BROAD VALLEYS.

The boundary between the hills and the valley bottom is not abrupt, because the plain has been alluvially built up along the border and the structural angle is obscured. There is, however, a usual change within a quarter to a half mile from an appreciable or steep slope in the hills to the angle of the plain, which appears almost level to the eye. The floors of the valleys of the foothill belt begin at an elevation between 800 and 600 feet and slope gradually toward the San Joaquin Valley. The floor of the large valley begins at the edge of the hills at an elevation of 500 or 600 to 300 feet, and slopes within a short distance to the general level surface of the plain, which lies between 400 and 200 feet above the sea. Within the district the surface of the San Joaquin Valley slopes almost imperceptibly southward to the basin of Tulare Lake.

The side valleys that branch out from the San Joaquin Valley between the inclosing ridges of foothills and mountains are Pleasant Valley and its continuation in the Kettleman Plain, and McLure Valley. Just outside of the district are the analogous basins of Waltham Valley on the west, which is almost entirely inclosed by hills, and Antelope Valley southwest of Avenal Ridge. All these valleys are structurally basin-like depressions whose streams have gained outlet to the plain through gaps either newly produced or deepened by erosion during the progress of formation of the basins.

TULARE LAKE.

The only lake within the Coalinga district is Tulare Lake, which borders the southeastern portion of the district east of the Kettleman Hills. It is a broad, shallow body of water occupying a portion of the almost level floor of the San Joaquin Valley and deriving its supply of water from several rivers that descend from the Sierra Nevada and spread numerous distributaries over the valley. Little or no surface water reaches the lake from the mountains on the west, although they are much nearer. The lake has no regular outlet, but in periods of high water the whole central portion of the valley to the north and south becomes flooded and marshy. Formerly the lake was one of the largest bodies of fresh water in California, but in late years it has been gradually declining in size, owing largely to the use of the water of its tributary streams for irrigation, to the construction of dikes, and to the reclamation of the land formerly covered by it. In 1880 it spread over an area about 27 miles long from northwest to southeast and 20 miles broad from northeast to southwest. Nine years later it was about 20 miles long from east to west and 15 miles broad from north to south. In still more recent years successive dikes had been constructed, the lake had almost dried up,

and most of the area formerly covered by it had been brought under cultivation. But the unusual precipitation of 1907 caused the whole central portion of the valley to be inundated, and extended the lake to approximately its old shore line of 1880, almost at the base of the Kettleman Hills. The accompanying topographic map (Pl. I), which was made in the summer of 1907, shows the abnormally high mark reached by the lake at that time.

During the late Quaternary period Tulare Lake covered a much greater area than at present, as is shown by the presence of an old beach at an elevation of more than 100 feet above its present level, 2 or 3 miles west of the northwestern corner of the lake as shown on the map, and also by marked shore lines at lower elevations. The old beach consists of a ridge of sand about 20 feet wide and 6 to 8 feet high, somewhat eroded and covered with low vegetation, which runs for a mile or so along the low slope flanking the Kettleman Hills. Its present elevation is probably due in part to the progress of recent relative uplift of the hill area. Benches marking other positions of the shore line are observable along the Dudley-Lemoore road between the lake and the Kettleman Hills, at an elevation of much less than 100 feet above the lake.

Tulare Lake marks the lowest area in the Coalinga district and, in fact, in the whole southern end of the interior valley of California. Its surface lies a few feet less than 200 feet above the sea. North of the lake a broad zone of greater elevation crosses the San Joaquin Valley and forms a barrier diverting the drainage from the southern portion of the Sierra Nevada southwestward into the lake basin. To the south the valley floor on the side toward the Coast Ranges has a general elevation between 200 and 300 feet. A line of depression west of the middle of the valley connects Tulare Lake, by a low tract subject to marshy inundations, with Kern and Buena Vista lakes, which lie in the southern end of the valley at an elevation of a little less than 300 feet.

The origin of the basin occupied by Tulare Lake is probably due to the building up of alluvial fans across the San Joaquin Valley north of it by the rivers of the Sierra Nevada, especially Kings River, and by Los Gatos Creek and the other creeks of the northern part of the Coalinga district, which have formed an unusually large alluvial fan for the Coast Range streams.

DRAINAGE COURSES.

Character of streams.—The main streams within the Coalinga district partake of the nature of all the streams flowing off the eastern flank of the Diablo Range. They are comparatively short mountain streams of medium gradient that flow from the mountains at short intervals in broad V-shaped valleys between the mountain spurs, and have many tributary streams a few miles in length with steeper

gradient and sharper valleys. Several terraces appear in many places along the sides of the stream courses within a few hundred feet above the present bottom, marking the position that the valley floor has occupied at different stages. (See Pl. IV, *A*.) The streams approach the plain through the lower hills with nearly graded or in places aggraded courses, emerge upon it over the gently sloping alluvial fans that they have built up, and form squarely cut, broad, shallow channels through the horizontal deposits of the valley floor or spread out and end as level washes. The dryness of the region does not allow them to reach any trunk stream, and the great valley is like a sea in bringing them to an end and forming a catchment basin. As before stated, none of the main streams in the Coalinga district heads within the area shown on the map. Owing to the slight rainfall and the prolonged drought in summer, none of these streams carries much water, and they all become nearly dry at the surface during that season.

The two most important streams of the district are Los Gatos Creek and Waltham Creek, which drain considerable tracts and flow through deep, structurally important valleys, in their lower portion nearly graded. These streams join in Pleasant Valley and pass out to the San Joaquin plain through a narrow gap cut across the uplift of the Coalinga anticline.

The next most important streams are Jacalitos and Avenal creeks, and these with four others, Zapato, Canoas, Garza, and Big Tar creeks, complete the list of main streams. Of all of these much the same may be said. A common feature is that the main upper forks of these streams flow at an oblique angle to the range from northwest to southeast or from west to east, and that they change their course toward the northeast in the lower portion and flow directly away from the range across the structural lines.

Los Gatos Creek.—Los Gatos Creek, the northernmost of the streams flowing off the Diablo Range in the Coalinga district, heads at Benito Pass, the divide between the San Joaquin Valley drainage and San Benito River, and flows southeastward with low gradient for about 30 miles to the plain. In the mountainous region it occupies a broad valley formed by well-worn ridges that slope gradually down into it from the flanks of the high ridges on the north and south. On reaching Pleasant Valley, like the other streams of this region, it forms a wide, shallow channel, with abrupt sides usually about 5 to 20 feet in height exposing the level deposits of the floor, and finally spreads itself out as a wash on the San Joaquin plain.

It is joined by an important tributary, White Creek, which heads on Joaquin Ridge, and after flowing off the flanks of this ridge follows the same general valley as Los Gatos Creek, the two streams being separated by a fairly sharp structural ridge 500 to 700 feet high above the valley bottom. The floor of the valley of Los Gatos

Creek, which is a few hundred feet wide at the widest, is crossed and recrossed by the meandering stream, and along its sides at the lower levels terraces representing former positions of the floor are evident. White Creek, owing to its mineral nature, has formed a hard cemented pavement of the stream gravel and has left terrace cappings of hard conglomerate along its sides. The low hills at the head of Pleasant Valley on either side of Los Gatos Creek are distinctly terraced at different levels and capped with coarse deposits of stream wash.

Waltham Creek.—Waltham Creek, a few miles south of Los Gatos Creek, enters Pleasant Valley near Coalinga. It rises in the heart of the Diablo Range as the main drainage feature of Waltham Valley, which is a broad structural depression with low interior relief between the two main spurs in this part of the range, namely, Juniper Ridge and the ridge farther west that forms the watershed between San Joaquin Valley and the area that drains directly to the ocean through the Salinas Valley. The main forks in the upper portion of Waltham Creek run southeast. At the edge of the area shown on the map the stream leaves the open Waltham Valley and enters Alcalde Canyon (at the point shown in Pl. V, *A*) through a sharp gorge cut to a depth of 800 or 900 feet across the sandstone and shale strata forming Juniper Ridge and Curry Mountain. Thence for 3 or 4 miles the canyon extends toward the west as a curving gorge with steep sides and graded floor, in places several hundred feet wide, and then turns abruptly northeast and opens out in the foothill belt into a straight, wider valley. The straight course of this lower portion of Alcalde Canyon is continued backward as a belt of low relief along the southeast end of Curry Mountain, but instead of coming from this apparent structural continuation of the lower part of its course the stream has cut the gorge already mentioned across the higher area to the north.

Jacalitos Creek.—The next stream to the south is Jacalitos Creek, which is only a few miles from Waltham Creek and like it rises on the slopes surrounding the Waltham Valley line of depression, flows southeastward in that depression, cuts a canyon directly out into the foothill belt, and flows northeast to the plain in a broad, low, fairly graded valley. It joins Los Gatos and Waltham creeks in Pleasant Valley. A portion of its tributary, Salt Creek, is shown in the foreground in Plate II, *B*.

Avenal Creek.—The southernmost stream in the district is Avenal Creek, which flows southeastward in a canyon between Castle Mountain and Avenal Ridge and follows a well-graded course through the wide McLure Valley. Above the head of the valley it follows a ravine between Avenal Ridge on the southwest and a low ridge of knolls that forms a continuation northwestward of the Tent Hills, this ravine being along the contact between the Cretaceous beds and the middle Miocene (Santa Margarita?) white shale. (See Pl. IX, *A*.)

The structural axis of the McLure Valley is farther east and marks the course of a minor stream. Avenal Creek breaks eastward across the row of hills mentioned, to enter McLure Valley, as may be seen in the middle distance in Plate IX, *A*. On the east side of McLure Valley it passes out through Dagany Gap, and thence its drainage course extends over Kettleman Plain and across the line of uplift of the Kettleman Hills through Avenal Gap, becoming lost on the floor of the great valley beyond. It is said that Avenal Creek has been known within comparatively recent years to drain around the southern end of the Kettleman Hills.

Other main streams.—Zapato, Canoas, Garza, and Big Tar creeks are parallel and similar streams that cut V-shaped canyons through Reef Ridge and flow in fairly straight, low, open valleys across the foothills to Kettleman Plain. The canyons in Reef Ridge are sharp and deep and form marked features of the topography, as illustrated in Plate VIII. The drainage courses of the first three streams join and pass to the San Joaquin Valley through Polvadero Gap. Big Tar Creek drains southward down the Kettleman Plain and out through Avenal Gap. Stream terraces, as shown in Plate IV, *A*, have been formed along the courses of some of these streams.

Minor drainage courses.—In addition to a number of main forks toward the head of the streams already mentioned, which have courses similar to the main streams, there are a great number of minor drainage lines of different character that either pursue independent courses to the edge of the plain or form tributaries at right or nearly right angles to the main streams. In places these in turn are entered at sharp angles by tributary gulches of considerable size, but ramifications of a higher order have rarely developed above the stage of swales or steep gullies. In the mountains and higher hills the minor drainage courses are for the most part sharp V-shaped canyons and arroyos. In the more gently sloping hills they are open ravines with rounded contours. On entering the plain these streams cut sharp channels in the soft filling of the valley, as shown in Plate XII, *A*.

PHYSIOGRAPHIC DEVELOPMENT.

FACTORS INFLUENCING DEVELOPMENT.

The most apparent feature of the topography on the eastern flank of the Diablo Range is its reflection of the structure of the formations, the controlling factor in the development of the physical features having been the folding and faulting of the strata. The broader features of the relief as well as a large proportion of the minor ones have been formed in accordance with the structure. A further factor, the differences in the rocks, especially in degree of induration, has played an important part in regulating the rate at which development has taken place and in modifying the forms due to structural features.

The climate likewise has acted as a modifying factor in the weathering of the strata and as a cause of local variation in the processes of erosion.

The chief processes by means of which physiographic change has been brought about have been orogenic movements, aqueous erosion, and aggradation. A further process of importance, sufficient to warrant mention, is gravitational degradation, especially by means of landslides, which are numerous in the somewhat incoherent strata of this region. Forces producing changes of elevation, both broadly and locally, have been continually active up to late geologic time and have left no areas unaffected, and the progress of every physiographic change begun within the late Tertiary and the Quaternary periods has been complicated by modifying movements.

HISTORY OF PHYSIOGRAPHIC DEVELOPMENT.

Some of the broad physiographic changes of early periods in this region will be outlined in the discussion of the geologic history. In the present connection the evolution of the topographic features during the period subsequent to the first great movements of the Quaternary will be taken up. These movements took place at the close of the period represented by the Tulare formation, which comprises the youngest strata of the region that are markedly displaced from their original horizontal attitude. The movements were probably contemporaneous with those occurring in the early Quaternary along the California coast and were long continued. They brought about the uplift and tilting of all the post-Eocene formations, which up to that time had probably not been severely disturbed, and caused the older strata to be upheaved in the axis of the mountainous belt, which had been previously determined and over which processes of degradation had been at work in earlier periods. The mountains were thus given pronounced relief and their topographic youth was renewed. The later Tertiary and early Quaternary deposits, as yet in large part incoherent strata, were raised on the flanks of the mountains and probably locally on the crest. With this uplift came acceleration of the erosional processes. The old streams began to flow with greater vigor, to cut their valleys deeper into the mountains, and to extend them farther and farther outward upon the strata that were being lifted up out of the plain. The uplift was so gradual that these streams, and the others which began forming down the slope of the blocks that were being tilted, planed off large portions of the lower areas almost as fast as they were lifted, and were able to keep their course across lines of relief that were raised beneath them. The main preexistent streams probably followed the old structural lines that form the main valleys at present, such as those of Los Gatos and White creeks, Waltham Creek, and Avenal Creek.

The streams that were formed subsequent to the first of these movements, tributary to the main streams that followed the structural lines, were consequent upon the structure, in that they took their course down the dip slopes determined by the new movements. They thus became fixed in courses at right angles to the main valleys, and in turn they themselves acquired tributaries at right angles that were determined by the strike of soft zones of strata. In this way the present topographic forms both in the mountains and foothills were eventually developed in accordance with the folds and the stratification.

It can not be stated whether the process of uplift was continuous or whether one or more periods of quiet intervened, allowing part of the planation to take place during periods when no movement was affecting the region. As the movements continued the partly planed surfaces were warped along the axes of disturbance and new cycles of erosion commenced to affect them. The appearance of the surfaces so tilted in the foothill region has been mentioned. They reflect the major anticlinal and synclinal folds and their plunges. It can not be said, however, that all such remnants of surfaces of planation are relics of the erosion that took place in the Pleistocene. There are many that are older, especially in the mountainous belt. The slopes that have been mentioned on the eastern flank of Juniper Ridge and extending down into the Alcalde Hills give a good illustration of the preservation of the pre-Miocene surface of the Cretaceous rocks, and of the early Miocene surface of the beds locally preserved as a little-disturbed capping over them.

During the latter part of the Quaternary, and perhaps during most of it, the main synclinal troughs in their more depressed portions have acted as basins for receiving much of the large amount of material worn from the higher regions. They have thus become aggraded into wide, almost level plains, such as Pleasant Valley, Kettleman Plain, McLure Valley, and the great San Joaquin Valley. The smaller valley bottoms have also been aggraded to some extent, as in the case of the lower portions of Alcalde Canyon, the valley of Los Gatos Creek, and some others of the larger streams, but the filling is not so deep as in the main valleys, and the majority of the small stream courses are not filled. The latter fact, taken with the occurrence of stream terraces at various levels (such as shown in Pls. IV, *A*; IX, *A*; and XI, *A*) and of bluffs due to undercutting along stream banks, indicates that most of the streams are actively engaged in eroding their valley bottoms, the cause probably being the continuance of upward movement along the already existent belt of topographic relief.

The general stage of development of the topography is youthful, although some areas, especially in the foothill belt, have reached

an advanced stage of youth approaching maturity. The course of physiographic development in the mountains and in the foothills has been similar, and the resulting type of topographic features due to the reflection of the structure is much the same. But modifications of the type have been caused by other factors, especially the difference in hardness and compactness of the strata in the two regions. In the mountains the Cretaceous strata which cover most of the region are well indurated and fairly homogeneous. The development has therefore been retarded, has been more even, and is now in a youthful stage. In the foothills the formations are largely soft, but are of various degrees of induration. Erosion has been rapid and has been able to gain a strong foothold along certain zones. In consequence, the features of certain parts of the hills, especially in the southern portion of the Kettleman and Kreyenhagen hills and along the soft zones elsewhere, are well worn and have an old appearance. The reason for the greater amount of wear to which the foothills in the southern portion of the Coalinga district have been subjected may be that the streams flowing off the Diablo Range were during much of the Quaternary period concentrated on that portion of the region by following a course southward along the synclinal depression of the present Kettleman Plain, being later directed into their modern channels by a warping across the northern portion of the Kettleman Plain determining the drainage divide in the plain and the rise of the anticline in the north-central part of the Kettleman Hills. It may be supposed that the streams wore down the southern portion of these hills as they were being uplifted, and cut the present Avenal Gap. The other similar gaps in the Coalinga anticline uplift, however, must be explained, and it is difficult to see how the streams on the north could have formed these gaps otherwise than by following their original courses continuously throughout the period of uplift. A possible hypothesis in explanation of the progressively greater amount of degradation that has taken place southward within the district is that a general tilting took place after the main original movements, causing the whole region to slope southward as it does at present. The mountains decline in height from the San Carlos division toward Antelope Valley, as has been brought out elsewhere; the foothills and the plains do the same, and the drainage, even where not determined by the main structural axes that plunge toward the southeast, has a predominant southeasterly course. The movement producing such a regional tilting, either through progressively greater depression toward the south or through uplift toward the north, might have been of similar nature to that occurring in former periods which caused the thickening and greater completeness of all the post-Eocene formations toward the south as compared with their continuation toward the north.

GEOLOGY.

GENERAL STATEMENT.

The eastern slope of the mountains bordering the San Joaquin Valley is formed by strata of great thickness dipping toward the valley. The oldest rocks exposed appear in the axis of the mountain range at the base of the monocline, and thence eastward successively younger formations appear as the edge of the valley is approached. The different formations that may be recognized as units in this series, with the time divisions to which they correspond, are as follows, from the oldest to the youngest: Franciscan (Jurassic?), Knoxville (Lower Cretaceous), Chico (Upper Cretaceous), Tejon (Eocene), Vaqueros (lower Miocene), Santa Margarita (?) (upper middle Miocene), Jacalitos (early upper Miocene), Etchegoin (uppermost Miocene), Tulare (Pliocene and early Pleistocene), and Quaternary alluvium and terrace deposits. These formations, with the exception of certain igneous and metamorphic rocks associated with the Franciscan, are of sedimentary origin. With the exception of the greater portion of the Pliocene and Quaternary and of minor amounts of the earlier Tertiary deposits, these sediments are marine. They indicate that the greater portion of the area included within the Coalinga district was beneath the sea during periods occupying probably the major portion of the time from the Jurassic to the end of the Miocene. Yet the unconformities separating all of these formations from one another show that intervals occurred during which no sediments were deposited, and that even with the enormous thickness of strata that is preserved the record is by no means complete. In general it is more complete in the southern than in the northern portion of the district, and most of the maximum thicknesses given are based upon the occurrences there. The record generalized in the columnar section may be more complete than the number of unconformities would seem to indicate, since probably not all are present in all parts of the district.

The accompanying columnar section (fig. 2) gives a generalized résumé of the lithologic character, relations, and maximum thickness of these formations as they appear in various parts of the Coalinga district. It can not, however, convey a conception of the variation of the formations in different parts of the district, which the descriptions of them that follow show to be a characteristic feature. Much detailed field work and paleontologic study have still to be accomplished before a final adjustment of the complex problems of correlation of the formations within the Coalinga district may be reached. The table on page 48 summarizes what is known of the age of the formations of the district and their time relation to the formations in other portions of the Coast Ranges.

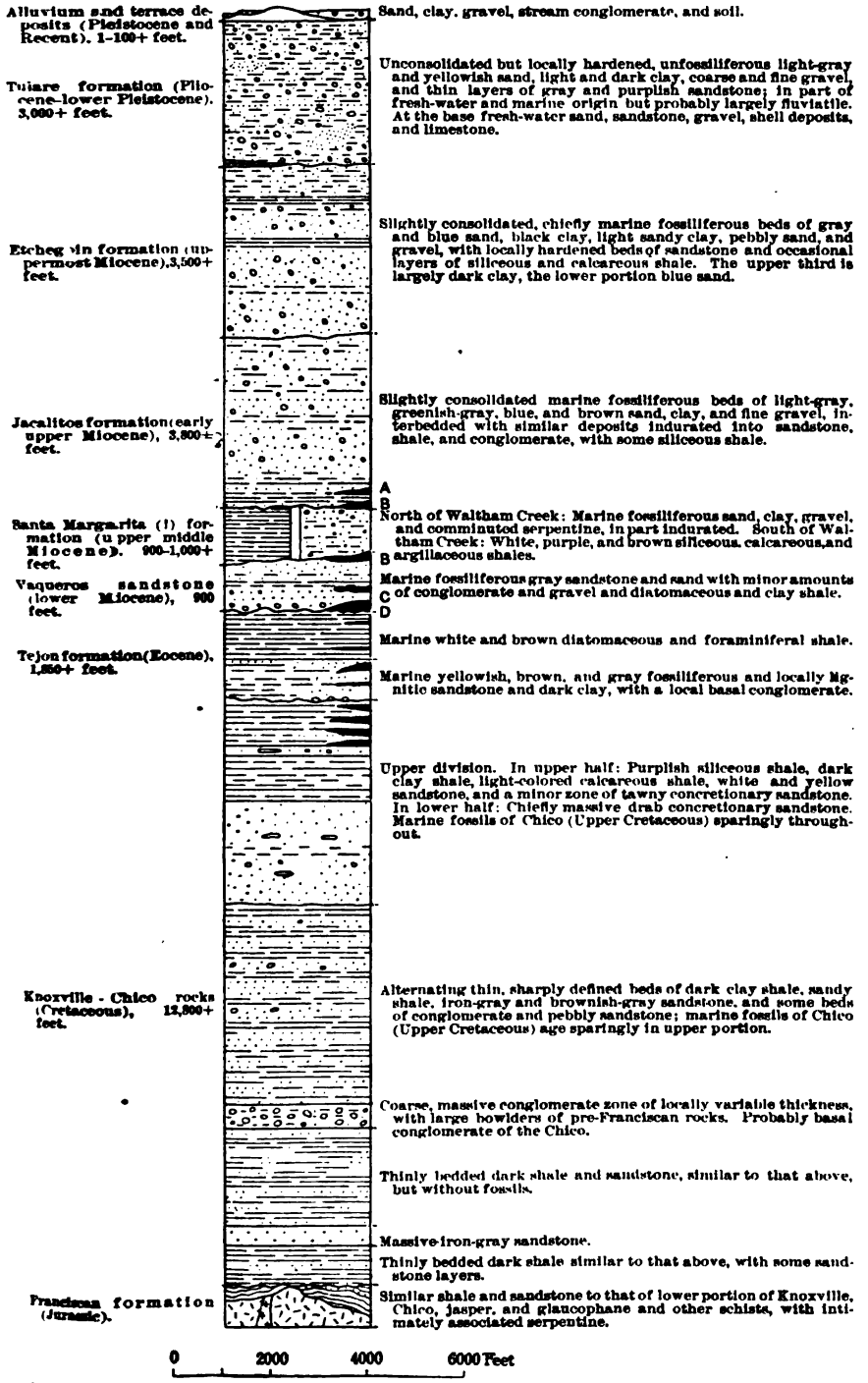

Alluvium and terrace deposits (Pleistocene and Recent). 1–100+ feet.
Sand, clay, gravel, stream conglomerate, and soil.
Tulare formation (Pliocene–lower Pleistocene). 3,000+ feet.
Unconsolidated but locally hardened, unfossiliferous light-gray and yellowish sand, light and dark clay, coarse and fine gravel, and thin layers of gray and purplish sandstone; in part of fresh-water and marine origin but probably largely fluviatile. At the base fresh-water sand, sandstone, gravel, shell deposits, and limestone.
Etchegoin formation (uppermost Miocene), 3,500+ feet.
Slightly consolidated, chiefly marine fossiliferous beds of gray and blue sand, black clay, light sandy clay, pebbly sand, and gravel, with locally hardened beds of sandstone and occasional layers of siliceous and calcareous shale. The upper third is largely dark clay, the lower portion blue sand.
Jacalitos formation (early upper Miocene), 3,800+ feet.
Slightly consolidated marine fossiliferous beds of light-gray, greenish-gray, blue, and brown sand, clay, and fine gravel, interbedded with similar deposits indurated into sandstone, shale, and conglomerate, with some siliceous shale.
A
B
Santa Margarita (?) formation (upper middle Miocene). 900–1,000+ feet.
North of Waltham Creek: Marine fossiliferous sand, clay, gravel, and comminuted serpentine, in part indurated. South of Waltham Creek: White, purple, and brown siliceous, calcareous, and
B argillaceous shales.
Vaqueros sandstone (lower Miocene), 900 feet.
Marine fossiliferous gray sandstone and sand with minor amounts
C of conglomerate and gravel and diatomaceous and clay shale.
D
Tejon formation (Eocene), 1,850+ feet.
Marine white and brown diatomaceous and foraminiferal shale.
Marine yellowish, brown, and gray fossiliferous and locally lignitic sandstone and dark clay, with a local basal conglomerate.
Upper division. In upper half: Purplish siliceous shale, dark clay shale, light-colored calcareous shale, white and yellow sandstone, and a minor zone of tawny concretionary sandstone. In lower half: Chiefly massive drab concretionary sandstone. Marine fossils of Chico (Upper Cretaceous) sparingly throughout.
Knoxville - Chico rocks (Cretaceous), 12,800+ feet.
Alternating thin, sharply defined beds of dark clay shale, sandy shale, iron-gray and brownish-gray sandstone, and some beds of conglomerate and pebbly sandstone; marine fossils of Chico (Upper Cretaceous) age sparingly in upper portion.
Coarse, massive conglomerate zone of locally variable thickness, with large bowlders of pre-Franciscan rocks. Probably basal conglomerate of the Chico.
Thinly bedded dark shale and sandstone, similar to that above, but without fossils.
Massive iron-gray sandstone.
Thinly bedded dark shale similar to that above, with some sandstone layers.
Franciscan formation (Jurassic).
Similar shale and sandstone to that of lower portion of Knoxville, Chico, jasper, and glaucophane and other schists, with intimately associated serpentine.
0
2000
4000
6000 Feet

FIGURE 2.—Generalized columnar geologic section of the sedimentary rocks of the Coalinga district. Oil zones shown in solid black. Letters A, B, C, D at right of section indicate oil zones, so designated in text.

Tentative correlation of formations of the Coalinga district with the standard California Coast Range section and with those of other localities in California.

Era.	System.	Series.	Standard Coast Range section.	Coalinga district section.	Santa Maria district section.	Santa Clara Valley (Ventura County) section.	Los Angeles and Puente Hills section.	Santa Cruz Mountains section
Cenozoic.	Quaternary.	Recent.	Alluvium.	Stream conglomerate and alluvium.	Alluvium.	Alluvium.	Alluvium.	Alluvium.
		Pleistocene.	San Pedro.	Stream deposits, valley fillings, and raised beach.	Terrace deposits and dune sand.	Terrace deposits, sand, and gravel.	Terrace deposits, sand, and gravel.	Terrace deposits, sand, and gravel.
			——Unc.——	——Unconformity——	——Unconformity——	——Unconformity——	——Unconformity——	——Unconformity——
	Tertiary.	Pliocene.	Unc. Merced.					Merced Santa Clara.
			San Diego.	Tulare.				
				——Unconformity——				
		Miocene.	San Pablo.	Etchegoin.	Fernando.	Fernando.	Fernando.	Purisima.
				——Unconformity——				
			——Unconformity (?)——	Jacalitos.				Santa Margarita.
			Santa Margarita.	——Unconformity——				
			——Unconformity——	Santa Margarita (?).	——Unconformity——	——Unconformity——	——Unconformity——	——Unconformity——
			Monterey.	Lacking (with possible exception of a small part).	Monterey.	Modelo: Shale. Upper sandstone. Shale. Lower sandstone.	Puente: Upper shale. Sandstone. Lower shale.	Monterey.
								——Unconformity——
			——Unconformity——					Vaqueros.
			Vaqueros.	Vaqueros.	Vaqueros.	Vaqueros.		
			——Unconformity——	——Unconformity——				San Lorenzo.
		Oligocene.	San Lorenzo.	Wanting (?).				——Unconformity (?)——
			——Unconformity (?)——		Sespe and Tejon, undifferentiated.	Sespe: Upper beds. Red beds. Lower beds.		Undifferentiated Eocene, probably Martinez.
		Eocene.	Tejon.	Tejon.		Topatopa.		
			Martinez.	——Unconformity——				
			——Unconformity——					——Unconformity (?)——
Mesozoic.	Cretaceous.		Chico.	Chico.	(?)			Chico.
			——Unconformity——					
			Horsetown.					
			——Unconformity——					
			Knoxville.	Knoxville.	Knoxville.			Knoxville.
			——Unconformity——	——Unconformity——	——Unconformity——			——Unconformity——
	Jurassic (?).		Franciscan.	Franciscan.	Franciscan.			Franciscan.
			——Unconformity——			——Unconformity——	——Unconformity——	——Unconformity——
			Granitic rocks, schist, etc.			Granitic rocks, gneiss, etc.	Granitic rocks, gneiss, etc.	Granitic rocks.
	(?)		——Unconformity——				Unconformity	——Unconformity——
			Schist; limestone.				Black schist.	Schist, limestone.

ROCKS IMPORTANT WITH RELATION TO PETROLEUM.

The strata older than the upper part of the Cretaceous are of little importance in this district in connection with the occurrence of petroleum. The uppermost Chico (Upper Cretaceous), Tejon (Eocene), and Vaqueros (lower Miocene) are the principal sources or reservoirs of the oil, and therefore of prime importance. The Santa Margarita (?) (upper middle Miocene) and Jacalitos (early upper Miocene) are petroliferous only at their base, and their higher beds together with those of the Etchegoin (uppermost Miocene) are the strata which overlie the oil sands and through which the wells are drilled, so that their relation, thickness, character, and structure have an important bearing upon the problem of accessibility of the oil and are worthy of detailed study. The Tulare (Pliocene-lower Pleistocene) is of less direct importance in this connection, but aids in throwing light upon the structure and the relation of the different formations.

ECONOMIC DEPOSITS OTHER THAN PETROLEUM.

The present report does not aim to discuss fully any of the economic deposits except petroleum.

The vicinity of Coalinga was known for its coal deposits before its rich oil resources were discovered, and an attempt was made many years ago to mine the coal. Two mines were started on the west side of Pleasant Valley by the San Joaquin Valley Mining Company, but the enterprise proved unprofitable. The coal is lignitic and occurs in thin local beds varying in thickness up to a foot or two. The lignite is usually crumbly and grades into seams of carbonized wood. It is interbedded with extremely varied gypsiferous sand and clay in the Tejon formation (Eocene), which is characterized by coal deposits at various other points in California.

There is a large quantity of gypsum in the Coalinga district. All the Tertiary formations are extremely gypsiferous and local seams of gypsum are present in the Cretaceous rocks as well. It usually occurs in the form of thin platy crystals filling joint cracks or occupying spaces along the bedding planes, or as crystal masses occupying irregular cavities. It is frequently so abundant that it permeates throughout certain beds, and either forms a hard cement for the original material or makes up almost the whole of the bed. Such deposits are of practically no economic value, owing to the impossibility of getting the material in a pure state. Gypsum likewise occurs locally in efflorescent surface deposits of soft white gypsite, as on the surface of the Tejon (Eocene) formation on a point of the hills at the edge of Pleasant Valley about 5 miles northwest of Coalinga and on the surface of the Vaqueros sandstone (lower Miocene) just east of Oil Canyon, 8 miles due north of Coalinga. An analysis of material

from the former locality, made by R. C. Wells, of the United States Geological Survey, showed it to contain 71.6 per cent of calcium sulphate (equivalent to 42.2 per cent SO_3) and 0.8 per cent of silica. These deposits have been mined on a very small scale, but they are not extensive. The gypsum of the Coalinga district and the surrounding regions is discussed in a paper by F. L. Hess on the gypsum deposits of California, issued as Bulletin 413 of the United States Geological Survey.

SEDIMENTARY FORMATIONS.

FRANCISCAN FORMATION (JURASSIC?).

GENERAL DESCRIPTION.

The central portion of the Diablo Range is occupied by an old and for the most part much altered formation that is in every way similar to the well-known Franciscan formation of other parts of the State. It comprises the oldest rocks here exposed, as it antedates the Knoxville (Lower Cretaceous), but further than this little can be said regarding its age. There is no definite fossil evidence of the age of the Franciscan elsewhere, and in this region none has been found, but from evidence obtained in various places in the Coast Ranges the formation is believed to be certainly pre-Cretaceous.

The areas covered by the Franciscan formation are easily recognizable, as they are characterized by typical rocks and topography. The most characteristic feature of these areas is the invariable presence of serpentine, which is associated with the formation and is usually classed and described with it owing to its intimate relationship, although it is in reality intrusive in the sedimentary rocks, and therefore later in age. The original sedimentary rocks, which are sandstone, shale, and jasper, occur in detached areas and are greatly disturbed. They are intermingled in a complex way with glaucophane, actinolite, and other schists, serpentine, and other metamorphic rocks, and one area of soda-bearing hornblende syenite is shown on the map. In the portion of the Coast Range within and bordering the Coalinga district the metamorphic rocks of the Franciscan formation greatly predominate over the unaltered. In the small area of Franciscan rocks in the northwest corner of the region the alternating beds of sandstone and shale closely resemble the strata in the lower portion of the Knoxville-Chico and are difficult to separate from them. If a larger portion of the Franciscan areas were covered by these unaltered rocks the formation would not be as easily distinguishable as it is stated to be at the beginning of this paragraph. In fact, the dividing line between the Franciscan and Knoxville-Chico has been drawn arbitrarily, and it will require further work to discover their true relations. It is possible that some of the dark shale and sandstone strata that appear at the base of the Knoxville-Chico in other

parts of the district, which have not been distinguished from that terrane owing to the absence of associated metamorphic rocks, may belong to the Franciscan, but the presence or absence of associated metamorphic rocks has been assumed as a basis of distinction between the formations.

The Franciscan beds in the northwestern corner of the district are chiefly sandstone. This rock is hard, gray, of medium coarseness, and somewhat thinly bedded and laminated so that it breaks into flat angular fragments. In places it appears to have undergone a process of alteration into a more quartzitic variety or to have been given a banded or flaky texture, as the result of crushing and elongation of the grains. The sandstone is interbedded with dark, fine-grained, thinly laminated clay shale, the laminæ of which are in places curved and smoothed as if by crushing. These rocks are exactly similar to those of the Franciscan farther north, in the mountains south of San Francisco Bay. Intimately associated with these beds are bluish glaucophane-bearing and micaceous schists in small patches. Jasper of green and variegated colors and both massive and banded structure is interbedded with the sandstone and shale in huge lentils. It was not observed within the area mapped, but forms striking outcrops farther west, especially in a group of picturesque buttes toward the head of Jacalitos Creek.

The serpentine covers a much larger area and extends far beyond the limits shown on the map, over a continuous stretch of high mountain country. The area that could be observed from the region at the head of Joaquin Ridge was estimated to be at least 40 square miles, and it is thought to be much more extensive. The Franciscan formation and associated rocks are considerably mineralized and contain deposits of cinnabar, asbestos, and the newly described gem mineral benitoite.[a]

IMPORTANCE WITH RELATION TO PETROLEUM.

The rocks of the Franciscan are not known to contain any petroleum. The formation is of different character from the formations in which the oil is found and has no direct relation to them. Even if it had once been a source of petroleum the disturbance that it has undergone could have allowed little to remain.

KNOXVILLE-CHICO ROCKS (CRETACEOUS).

GENERAL DESCRIPTION.

The next to the oldest terrane exposed in the Coalinga district is a thick series of strata of sandstone, shale, and conglomerate overlying the Franciscan formation and covering a wide belt for the

[a] Louderback, G. D., Benitoite, a new California gem mineral, with chemical analyses by W. C. Blasdale: Bull. Dept. Geology Univ. California, vol. 5, July, 1907, pp. 149-153. Also Arnold, Ralph, Notes on the occurrence of the recently described gem mineral benitoite; Science new ser., vol. 27, Feb. 21, 1908, pp. 312-314.

most part west of the foothill region. It forms the high ridges bordering the Coalinga district on the west and may be easily recognized by the dark, thinly bedded, compact shale and sandstone of its lower portion and the massive drab concretionary sandstone of its upper portion. These strata are of Cretaceous age and comprise part or all of the two formations well known elsewhere on the west coast as Knoxville (Lower Cretaceous) and Chico (Upper Cretaceous). Owing to the insufficiency of fossil or stratigraphic evidence as yet obtained in the Coalinga district to form the basis for a separation between these two formations, they are mapped and described together for the present.

The Horsetown formation, which forms the middle portion of the Cretaceous in the standard Coast Range section, is not known to be represented in the Coalinga district, although it is not impossible that a portion of the great thickness of nonfossiliferous Cretaceous strata may be the equivalent of this formation. No evidence, however, has yet been found of its presence in this portion of the Coast Ranges.

A conservative estimate places the total thickness of the strata mapped as Knoxville-Chico at 12,800 feet. The maximum thickness is probably much greater. This succession of strata may be divided lithologically into three main divisions. The total thickness of the middle and upper divisions, which are probably to be referred together to the Chico formation, is at least 9,500 feet. A thickness of 8,300 feet is measurable in single sections, and even greater thicknesses may be found in single sections of the Knoxville-Chico as a whole. It is likely that at least two unconformities separating the Knoxville-Chico beds into important stratigraphic groups will be made out on further study. Their relation likewise to the Franciscan below will in all probability be found to be an unconformable one. They are overlain unconformably by the Tejon (Eocene) and the later formations.

The Knoxville-Chico areas were not studied in detail, but it is thought best to record such partial information as has been obtained as a guide to future work. The line of separation of the lower and upper divisions—that is, the line of the conglomerate zone to be mentioned—is shown roughly on the geologic map (Pl. I) along the flank of Juniper Ridge and Curry Mountain. The line between the middle and upper divisions is shown on both arms of the White Creek syncline, being marked on the south arm by the Los Gatos Creek fault line.

LOWER DIVISION.

DISTRIBUTION AND CHARACTER.

A zone of coarse conglomerate varying in thickness from less than 100 to over 1,000 feet extends intermittently from the summit of Juniper Ridge south of Los Gatos Creek to a point south of

Reef Ridge in Big Tar Canyon. It is overlain and underlain, in appearance conformably, by the thin-bedded dark shale and sandstone of the lower half of the Knoxville-Chico. The portion of the terrane lying below this conglomerate is here classed by itself as the lower division. The strata of this division are well exposed in the upper portion of Alcalde Canyon and on Juniper Ridge to the north and Curry Mountain to the south. There a thickness of at least 2,000 feet of alternating thin beds of grayish-black shale, shaly sandstone, and fine sandstone of a dark-gray color underlies the conglomerate. At the base of these predominantly shaly beds there is an abrupt change in the rocks to massively bedded sandstone which forms the prominent ridge of Curry Mountain and the southern end of Juniper Ridge at the western edge of the mapped area, as shown in Plate V, *A*. This sandstone is iron-gray, hard, homogeneous, of medium grain, and only rarely pebbly, and has a thickness of about 300 feet. Below it, on the west side of the ridges mentioned, on the steep flank represented in the center of Plate V, *A*, outside of the mapped area, similar shale beds to those above the sandstone begin abruptly and make up a thickness of at least 600 feet. How much more there may be is not known, as the series was not examined, but it is thought that the lowest beds in the Knoxville-Chico in this section can not be much more than 800 to 1,000 feet below the sandstone of the ridge. Thus the total thickness of the lower division as exposed in the Alcalde Canyon section is between 3,100 and 3,500 feet. The base of the lower division is not known to be exposed anywhere within the area shown on the map, nor is any portion of the division known elsewhere than in the vicinity referred to and in the region south of Reef Ridge below the conglomerate near the head of Big Tar and Garza creeks. In that region a complex mingling of rocks of doubtful ages occurs, among which some, such as dark-blue clays and red shales, are not similar to others known in the district. These rocks are supposedly of Cretaceous age, and are so mapped.

EVIDENCE OF AGE.

Fossils of Knoxville (Lower Cretaceous) age, such as *Aucella crassicollis* Keyserling and *Belemnites impressus* Gabb, have been found in beds of dark shale in the Devils Den region not many miles south of the Coalinga district, and there is little doubt that the lower division of the rocks here described as Knoxville-Chico is at least in part the equivalent of the Knoxville formation. It is possible that the great beds of conglomerate mark the base of the Chico or Upper Cretaceous and that the whole of the lower division below this line of separation represents the Knoxville formation.

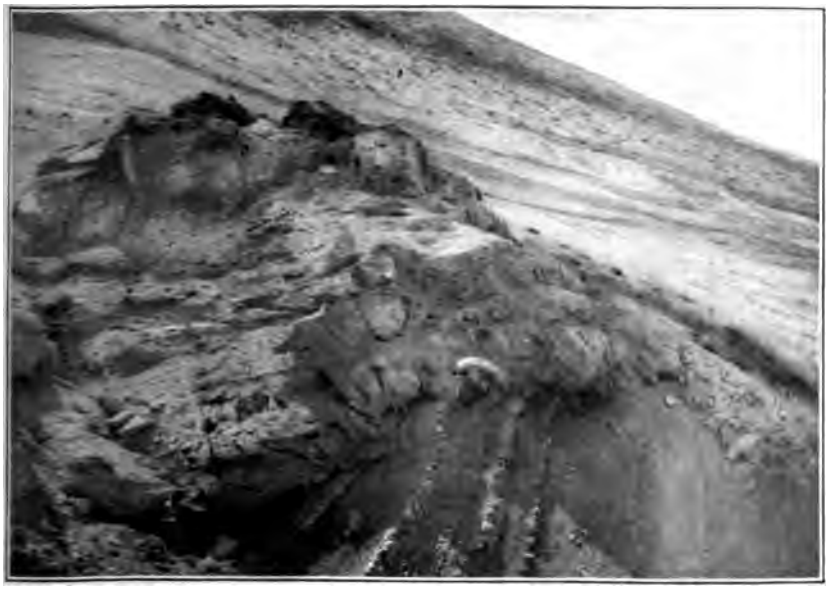
MIDDLE DIVISION.

DISTRIBUTION AND CHARACTER.

The middle one of the main divisions into which the Knox Chico rocks are divisible upon lithologic grounds comprises a t series of alternating thin beds of dark shale and sandstone witl above-mentioned heavy conglomerate at its base, and with characteristic massive, concretionary sandstone beds that form upper division overlying. Its thickness, including the conglom zone, measures at least 4,800 feet in the Alcalde Canyon section considerably more farther northwest on the flank of Juniper R because in the former section the upper portion is covered up by overlapping Miocene and the full thickness can not be meas The conglomerate is locally extremely variable and is not contin It may in places be traced directly into massive sandstone or into thinly bedded sandstone and shale, as along Alcalde Ca between 2 and 3 miles west of Alcalde. It represents throughou district, however, an important stratigraphic horizon characte by a coarsening of the sediments. On the northeast side of Al Canyon and again about 4 miles south of the confluence of Los C and White creeks it is a deposit of extremely coarse and well-hard conglomerate 200 to 300 feet in thickness. Near the head of Big Canyon, at the west edge of the mapped area, a thickness of 1 feet or more of coarse, hard conglomerate occurs within the C ceous shale, probably at the same position in the series. In vicinity it runs out of the area shown on the map and does appear within it again south of Curry Mountain. The dark s above it is continuous along the southwest side of Reef Ridge an conglomerate probably continues likewise. The thin-bedded s and sandstone of the middle division are well exposed in the la ridges of Joaquin Ridge south and east of the serpentine area, a heavy zone of massive conglomerate exposed near the head of W Creek may be the equivalent of the basal conglomerate elsew The rocks of this division cover most of the north and nort flanks of Juniper Ridge and Curry Mountain. South of Curry M tain there is no evidence of the relations of the different membe the Knoxville-Chico such as is exposed farther north, the Cretac being covered up unconformably by the Miocene beds south to Jasper Canyon. On Reef Ridge south of Jasper Canyon the u portion of the Knoxville-Chico is lacking, and there is little d evidence to indicate how large a portion is absent. The dark t bedded shale and sandstone of Reef Ridge may, however, be c lated with fair assurance with the middle member of the Knox Chico farther north, because it is similar in lithologic character because it is underlain in the region of Big Tar Canyon by the

A. WESTERN FACE OF CURRY MOUNTAIN, FORMED BY CRETACEOUS STRATA.

Probably a fault scarp. Looking south across Waltham Creek, which cuts through ridge at left. Waltham Valley on right and crest of Diablo Range in distance. Photograph by Ralph Arnold.



B. UNCONFORMITY BETWEEN TEJON FORMATION AND VAQUEROS SANDSTONE.

The petroleum migrates from shales below and [illegible] sand and gravel above to form oil zone D. In canyon of Laval grade, 8¼ miles north of Coalinga. Photograph by Ralph Arnold.

conglomerate zone before mentioned. The Cretaceous strata on Avenal Ridge are thought to belong chiefly to the middle division.

EVIDENCE OF AGE.

The beds of the middle division are for the most part nonfossiliferous, but here and there a few fossil mollusks are to be found in thin beds of conglomerate or scattered through the shale and sandstone. The fossils that have been obtained from this division of the Knoxville-Chico are listed under localities 4, 5, 6, and 10 (p. 60). Locality 11 is probably also in this division and locality 9 is possibly so. Among the fossiliferous beds of which the horizon has been stratigraphically determined those of localities 5 and 6 are the lowest, being about 2,000 feet below the top of the division, and the fossils prove the Chico or Upper Cretaceous age of the beds at least as far down in the terrane as this. As no break seems to occur in the middle division the whole is probably referable to the Chico, and the basal conglomerate the indication of a great time break between these beds and those of earlier Cretaceous time.

UPPER DIVISION.

DISTRIBUTION AND CHARACTER.

The uppermost of the three divisions of the Knoxville-Chico is predominantly concretionary sandstone in the lower part and shale in the upper part, and has a thickness of at least 4,700 feet. It is not known to be exposed in any but the northern portion of the district. It is separable into several members which show diversity of lithologic character, but no evidence points to any but a conformable relation between these members. On the contrary, the seeming intergradation between them and the recurrence at different horizons of peculiar types of deposits—such, for instance, as the concretionary sandstone—indicates continuity of deposition. Taken as a whole the upper division is strikingly distinct from other formations in the district and seems to represent a separate stratigraphic unit, although no unconformity has been made out at its base.

The lower half of the upper division consists chiefly of massive sandstone beds, often weathering cavernous, that stand out prominently and display the structure on the sides and tops of the ridges north of Los Gatos Creek and west of Coalinga. The sandstone is usually drab, medium grained, and not very hard. The rocks of this division may be easily recognized by these characteristic outcrops and by the numerous large, hard reddish-brown concretions of which the sandstone is full and which weather out and remain in patches upon the surface as shown in Plate IV, *B*. These concretions are of various forms, oval, round, flat, and lens-shaped, and of various

unsymmetric shapes, and have a tendency, as noted by F. M. Anderson, "to split horizontally or to fall apart in concentric shells or laminæ." They vary from small sizes up to a thickness of 8 or 10 feet. The prominent sandstone strata are separated by softer beds and zones of sand and light-colored shale, which are poorly exposed. Thin seams of calcareous shale and sand are at some points interbedded with the softer beds. Locally the sandstone is conglomeratic. At the base of this member of the Knoxville-Chico the massive sandstone beds give place to thinner beds alternating with finer-grained sandstone and shale, and these grade over into the thin-bedded series described as the middle division. The transition takes place within a few hundred feet and in places a fairly sharp line can be traced between the beds that are chiefly sandstone and those in which the thin layers of fine grain predominate.

Above the succession of concretionary sandstone beds, and forming the upper half of the upper division of the Knoxville-Chico, comes a less prominent and less uniform succession of beds in which shale is predominant. These beds form the uppermost Cretaceous exposed within the Coalinga district and are only with difficulty separable from the overlying Eocene beds. This upper half of the upper division consists of two main members predominantly of shale, each approximating 1,000 feet thick, separated by a much thinner but more prominent member of concretionary sandstone, in general similar to that lower down. Both of the shale members form belts of low topography, whereas the intermediary sandstone forms a row of hills separating them.

The lower of the two shale members has few exposures but is notable for the presence in it of different kinds of deposits, such as blackish, thinly-bedded clay shale and yellowish and whitish calcareous and arenaceous shale and sand, and for the presence of *Ammonites*, *Baculites*, *Inoceramus*, and other fossils, which weather out in a fragmentary state on the surface of the clayey soil. According to a personal communication received from Mr. F. M. Anderson it is from this shale member that he obtained the fauna listed from "the yellow shales below the concretionary sandstones" in his paper on the Diablo Range.[a] This fauna is given on page 61.

The sandstone separating the two shale members varies from 200 to 300 or 400 feet in thickness and consists of yellowish-gray and brown sandstone full of large brown concretions. It is of the same type as the characteristic Chico concretionary sandstone farther down in the section, but differs slightly in that the outcrops have in general a more brownish aspect, and that the concretions are of larger average size and in many places have the character of elongated layers. This sandstone is without fossils so far as known. It occurs

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, 1905, p. 161.

typically on the 2,500-foot hill 1½ miles northwest of Oil City, whence it is traceable northward beyond the northern edge of the area mapped and southwestward nearly to Los Gatos Creek.

The uppermost member is one of particular interest owing to its individuality among the known types of Cretaceous deposits, its large content of organic material, its petroliferous nature, and its similarity to the Eocene beds. It is at least 1,200 feet thick and consists principally of shale, but has a considerable admixture of sand and sandstone. For convenience it will be referred to as a whole as the purple-shale member. The most characteristic beds of this zone are of purplish-brown, fairly hard, thinly bedded, both siliceous and calcareous clay shale, in which the tests of Foraminifera are very abundant. This shale bears a resemblance to some of the less siliceous shale in the upper part of the overlying Tejon (Eocene), especially to that shale as it occurs in the southern part of this district, and is not unlike some argillaceous phases of the Monterey shale (middle Miocene) of the outer Coast Ranges and the shale mapped as Santa Margarita (?) (middle Miocene) along Reef Ridge and at other points in this district. It contains local thin, generally lenticular layers of grayish and yellowish calcareous shale and also large oval nodules of grayish-white limestone. These nodules are usually several feet in dimensions, and one was observed as much as 8 feet long and 2½ feet thick. Seams of sandy shale and lenses of sand occur sparingly.

Purple shale such as that described is especially characteristic of the upper half of the member and forms a well-marked belt of low topography, and locally bare purplish slopes dotted with dark-green juniper and oak trees, at Oil City and both northeast and southwest of that place.

In the lower half of the member the shale is less markedly of the purplish type and ordinary grayish-black clay shale, like that below the underlying concretionary sandstone, is an important constituent. Most of the shale, however, has at least a trace of the purplish color and contains Foraminifera. Calcareous layers and lenses occur throughout. The beds are characteristically much crushed, filled with seams and veins of selenite along the small cracks, and traversed by irregular sandstone dikes. Somewhat irregular zones of whitish, yellowish, and grayish fine-grained sand and sandstone are interbedded with the shale in the lower part of the member. For the most part these are more varied than the sandstone characteristic of lower portions of the Chico, are more thinly bedded, and lack the large brown concretions. Some of the true concretionary sandstone is interbedded with the shale, however, and no sharp line of separation is to be drawn between the purple-shale member and the underlying concretionary sandstone. The contact is shown on the map (Pl. I) by the green line bounding the west side of the possible productive territory north of Los Gatos Creek.

Above the purple shale of the uppermost Cretaceous lie dark clay and clay shale beds aggregating several hundred feet in thickness, which appear to form an upward continuation of the shale of the Chico, but which are mapped with the Tejon (Eocene). Fossils recently found near the northern edge of the Coalinga district show that the higher of these beds belong with the sandstone of the Tejon above; but there is reason to believe that 200 feet or so of beds at the base belong in the Chico. Their inclusion in the Chico would make no appreciable difference in the mapping and for the present the line is drawn at the top of the purple shale, which is the only line that could be mapped with any approach to consistency. Whether the line of separation between the Cretaceous and Tertiary occurs at the top of the purple shale or somewhat higher, within the darker clay shale, it is noteworthy that it should occur within a zone of fine sediments and be marked by no break of evident stratigraphic importance.

However, in spite of the apparent transition between the shale of the Cretaceous and that of the Eocene in the northern part of the Coalinga district, it is believed that they are separated by an unconformity. The evidence of this is the progressive disappearance of the upper members of the Knoxville-Chico southward in the district, whereas the basal Tejon is believed to represent a fairly constant horizon. The upper half of the upper division of the Knoxville-Chico has been recognized only north of Los Gatos Creek, and south of Waltham Creek the whole of the thick concretionary sandstone terrane has disappeared likewise, the Tejon where next exposed south of Jacalitos Creek resting directly upon dark shales of a lower portion of the Knoxville-Chico. The beginning of the disappearance of the upper members of the Cretaceous is indicated by the gradual thinning of the purple-shale member at the top southwestward from Oil City until it is finally lost near Los Gatos Creek. This thinning and disappearance of the members is probably the effect of erosion upon them before the deposition of the Eocene.

In the preliminary report on the Coalinga district[a] the shale and interbedded sandstone here described as the uppermost member of the Chico (Upper Cretaceous) was treated as part of the Tejon (Eocene) owing to its similarity to and striking appearance of continuity with the beds of that age. The line between the Cretaceous and Eocene was arbitrarily drawn at the top of the concretionary sandstone immediately underlying this member. During the course of work done north of the Coalinga district by the junior author of the present paper and R. W. Pack in 1909 it was discovered that this shale zone is part of the Cretaceous, the fact being especially confirmed for the Coalinga district by the finding of Cretaceous fossils such as *Baculites* and *Hamites* in calcareous nodules in the purple shale

[a] Bull. U. S. Geol. Survey No. 357, 1908.

within one-half mile northwest of Oil City (on the west side of the SW. ¼ sec. 17, T. 19 S., R. 15 E.). The stratigraphic relations and fauna of this shale will be further discussed in a report that is in preparation on the territory north of the Coalinga district.

The beds here referred to as the purple-shale member of the Chico (Upper Cretaceous) were mentioned by F. M. Anderson in his first paper on the Diablo Range.[a] He considered them to represent the middle portion of the Eocene of this region and correlated them with the shale on Reef Ridge in the southern part of the Coalinga district, which was termed by him the Kreyenhagen shales and which is described in the present paper as the upper member of the Eocene. In a paper published subsequently[b] the purple-shale member was described as the lower shales in a fourfold division of the Eocene, the underlying concretionary sandstone, which outcrops typically on the 2,500-foot hill northwest of Oil City, being described as the lower sandstone and considered as the base of the Eocene. Higher beds than any here referred to the purple-shale member were included in F. M. Anderson's description, as is shown by the fact that Eocene fossils were stated to occur in this division.

The upper division of the Knoxville-Chico presents approximately the following section on Joaquin Ridge:

Section of upper division of the Knoxville-Chico rocks 10 miles north of Coalinga.

	Feet.
The purple-shale member: Petroliferous, purplish and blackish, foraminiferal, siliceous clay shale, with calcareous nodules; decidedly purple and siliceous in the upper part; more argillaceous and intermingled with whitish and yellowish sand and sandstone in lower part; overlain by clay and sand of Tejon (Eocene)	1,200
Hard golden-brown sandstone, largely made up of irregular elongated concretions, forms 2,500-foot hill northwest of Oil City	200±
Soft zone of whitish-gray and yellowish-gray sand and dark clay shale, with occasional thin layers of hard brown sandstone and hard calcareous shale; forms low topography, few outcrops, and loose, crumbly soil	1,000
Hard brown sandstone with large reddish-brown concretions of hard sandstone, interbedded with whitish and yellowish-gray sand full of small bullet-like concretions of gray sandstone	300
Light-colored calcareous shale	200
Hard brown sandstone with some large concretions, interbedded with much less prominent beds of yellow sand	300
Massive beds of fairly soft yellowish-gray sandstone full of large dark-brown concretions, forming outcrops such as that shown in Plate IV, *B*. Softer beds of sand and clay that do not outcrop are interbedded. This is the top of the typical massive concretionary sandstone of the lower portion of the upper division of the Knoxville-Chico	200
Chiefly massive yellowish-gray sandstone like the last, with several zones in which the concretions are abundant and with some conglomerate zones; forms rocky pinnacles; overlies thinly bedded shale and sandstone of middle division	1,300+
	4,700+

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2 1905, p. 163.
[b] Idem, 4th ser., vol. 3, 1908, pp. 13-14.

EVIDENCE OF AGE.

Fossils of Chico (Upper Cretaceous) age have been found by the writers at various localities in sandstone, conglomerate, and shale in this upper division of the rocks mapped as the Knoxville-Chico. Most of them are in a poor state of preservation. The following species, all believed to be characteristic of the Chico, have been found in the upper and middle divisions within the district:[a]

Chico (Upper Cretaceous) fossils from the Coalinga district.

Name.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
PELECYPODA.											
Anomia lineata Gabb		×									
Anomia lineata? Gabb					×	×					
Arca vancouverensis Meek		×									
Avicula linguæformis Evans and Shumard										×	×
Inoceramus sp. indet				×						×	
Mactra ashburneri Gabb			×								
Meekia sella Gabb			×								
Meekia sella? Gabb		×									
Nucula sp. indet										×	
Pelecypod sp	×										
Solen? sp		×									
Tellina? ooides Gabb			×								
Venus varians Gabb		×									
GASTEROPODA.											
Lunatia sp			×								
Perissolax brevirostris Gabb				×							
Volutoderma gabbi (White)			×								
CEPHALOPODA.											
Ammonites[a]				×							
Baculites chicoensis Trask	×			×				×	×		
Pachydiscus n. sp.[a]							×				

[a] Fragments of indeterminate ammonoids have been found by several persons in the hills northwest of Coalinga.

1. Ten miles N. 27° W. of Coalinga, at elevation of 2,600 feet, on summit of long ridge north of Los Gatos Creek, in center of SW. ¼ sec. 15, T. 19 S., R. 14 E. About 1,000 feet stratigraphically above base of Chico concretionary sandstone series in a bed of conglomerate and pebbly micaceous sandstone.
2. Hills north of Los Gatos Creek; probably same locality as 1.
3. About one-fourth mile north of 1, on the same ridge. About 600 feet stratigraphically above base of Chico concretionary sandstone series in a conglomerate bed through massive sandstone.
4. On long ridge 3¼ miles north of junction of White and Los Gatos creeks, on north side of summit of 2,654-foot hill. Several hundred feet stratigraphically below base of Chico concretionary sandstone series in a coarse conglomerate through sandstone and shale.
5. Two miles north of White Creek, at elevation of 3,100 feet, one-fourth mile southeast of summit of 3,425-foot hill, southeast corner sec. 10, T. 19 S., R. 13 E. About 2,000 feet stratigraphically below base of concretionary sandstone series in a bed of pebbly sandstone through the shale series.
6. Two miles north of White Creek, at elevation of about 2,800 feet, on long ridge three-fourths mile south of 3,300-foot hill, east side of NE. ¼ sec. 14, T. 19 S., R. 13 E. About 2,000 feet stratigraphically below base of Chico concretionary sandstone series in a pebbly sandstone through shale series. Probably the same horizon as 5.
7. Hills northwest of Coalinga; locality indefinite. Specimens owned by J. H. Webb.
8. Float in creek 6 miles northwest of Coalinga, north of White Creek.
9. In Alcalde Hills, 3½ miles west-southwest of Coalinga in Anticline Canyon, central part of sec. 2, T. 21 S., R. 14 E. At contact of Cretaceous and Miocene in a thin bed of pebbly sandstone through thinly bedded sandstone and shale.
10. Alcalde Canyon, one-half mile southwest of Alcalde. In shale.
11. Head of Canoas Creek outside of the area mapped. About 1 to 2 miles east of the southeast end of Castle Mountain. In sandstone and shale.

The following additional species are reported by F. M. Anderson[b] from nodular limestone in the shales below one of the upper con-

[a] The fossils mentioned on p. 58 as occurring in the purple-shale member were found too recently to admit of their being listed here.

[b] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, p. 161.

cretionary sandstone zones of the upper division of the Knoxville-Chico at different points in the Coalinga region.

PELECYPODA.

Glycymeris veatchii Gabb+Pectunculus id.
Inoceramus whitneyi Gabb.

GASTEROPODA.

Architectonica sp.
Cinulia obliqua Gabb.
Gyrodes sp.

CEPHALOPODA.

Baculites sp.
Desmoceras sp., related to D. hoffmanni Gabb.
Lytoceras sacya Forbes.

The fossils prove the Chico age of the rocks throughout the upper division, leaving only a small thickness of strata at the summit, between the fossiliferous Chico beds and those containing Tejon (Eocene) fossils, of which the age is in doubt. These strata, which are at most a few hundred feet in thickness, might be either Chico or Tejon, or a transitional series corresponding in age to the Martinez formation in the vicinity of San Francisco Bay. A line of separation is drawn in the transitional portion on the basis of lithology, and it is believed that the beds below are with little doubt of Chico (Upper Cretaceous) age and those above, with the possible exception of 200 feet or so at the base, of Tejon (Eocene) age.

IMPORTANCE WITH RELATION TO PETROLEUM.

The purple-shale member of the Knoxville-Chico (Cretaceous) is of especial interest as the reservoir and presumably the source of the large amount of light oil that has been produced by the Oil City field. The wells obtain their oil from the sandy zones in the lower portion of the member and possibly in places also from the shale itself. The occurrence of petroleum in this formation affords the first instance known on the west coast of richly productive petroleum-bearing beds in the Cretaceous. The presence of oil may be detected in many places in the shale by the odor, especially in the calcareous layers and nodules, and it is not improbable that the purplish and chocolate-brown colors appearing throughout the member are due to petroleum staining. A seepage of light oil from the shale of this member within one-half mile northwest of the camp now called Oil City led to the first drilling for oil in the region and the consequent development of the Coalinga field. Another large seepage occurs near the forks of a canyon less than 2 miles northeast of Oil City (NW. ¼ sec. 9, T. 19 S., R. 15 E.).[a] There the oil is exuding from beds of dark clay in the middle of the clay zone already mentioned as overlying the purple-shale member. The beds at the horizon of the seepage are prob-

[a] Owing to an error in the engraving this seepage is shown one-fourth mile too far east on the geologic map (Pl. I).

ably in the Tejon (Eocene), but can not be far above the top of the Knoxville-Chico (Cretaceous), being, at most, within 400 feet stratigraphically above the top of the purple shale, from which the oil with little doubt comes. The seepage may be an indication of the horizon of the line of unconformity between the Cretaceous and Eocene.

No evidence of oil is known in the Knoxville-Chico strata at any horizon lower than the base of the purple-shale member. It is possible that traces of oil are to be found in them, as in most sedimentary rocks, but there is nothing to indicate that it will ever be discovered in this region in a quantity sufficient to make it of economic importance. No petroleum has been found by wells penetrating strata lower than the purple-shale member.

TEJON FORMATION (EOCENE).

GENERAL DESCRIPTION.

The formation mapped as the Tejon in the Coalinga district is made up entirely of sedimentary strata that dip toward the great valley in the monocline along the eastern flank of the mountains and are exposed on the surface in a narrow discontinuous belt between the Cretaceous beds which underlie them and those of the Miocene which overlie them. The beds so mapped have a thickness of 1,600 to 1,850 feet and are divisible into two main members of approximately equal thickness—a lower one consisting of sandstone in the southern part of the district and of dark clay shale and sand in the northern part, which is certainly of Eocene age, with the possible exception of a small thickness at the base, and an upper one of light-colored organic shale which affords few species of fossils and no conclusive evidence as to its age. This upper member may represent either Eocene or Oligocene time, but the facts that there seems to be a gradation from the beds of the lower member into those of the upper and that the two invariably occur together in this region favor its assignment to the Eocene. It is made up of thin beds of whitish and purplish siliceous, argillaceous, and locally calcareous shale, which is easily recognizable and which lends individuality to the formation. The shale is very similar, especially in some places, as north of Coalinga, to the siliceous shale of the formation along Reef Ridge that is described later as the Santa Margarita (?) formation, and the two must not be confused. It is also somewhat similar to the purple shale of the upper Chico. Where the Tejon formation is thick, shale and clay form a greater proportion of the whole than the sandstone, but a great local variation in the thickness of this member is noteworthy because due to the great unconformity between it and the overlying Miocene beds. A large portion of the formation had been worn away before the Vaqueros (lower Miocene) sandstone was deposited on its upturned surface. It is possible that an unconformity occurs

within the beds mapped as Tejon at the base of the upper shale, but no discrepancy in dip between the beds of the two divisions has been found, and the succession of beds is seemingly continuous.

As already pointed out, an unconformity exists between the Chico (Upper Cretaceous) and Tejon (Eocene) beds, in spite of the facts that no sharp line of demarcation is to be drawn between the Tejon and the underlying Chico in the northernmost part of the district and that there appears to be a gradation from the beds of the former into those of the latter, as if they had been formed during a continuous period of sedimentation. In the southern portion of the district the Tejon overlies unconformably beds that belong to an earlier portion of the Cretaceous, either lower Chico or Knoxville, thus proving that a period of land conditions and orogenic disturbances preceded the Tejon.

Tejon group was the name applied by J. D. Whitney to the fossiliferous strata in the vicinity of Fort Tejon, Kern County, and Martinez, Contra Costa County, which were included by Gabb under his Division B, or Upper Cretaceous.[a] As the result of later studies the fossils of this formation are now considered to be of Eocene age. Strata of the same age occur extensively in the region of Carquinez Straits, east of Mount Diablo, and have been found at a number of different points along the western border of the San Joaquin Valley, notably at New Idria and in the region discussed in the present paper. It may therefore be said that in all probability an almost continuous belt of Tejon sedimentary rocks extends near the valley edge between Martinez and the type locality in Kern County, this formation composing an important middle member in the succession of terranes of which the easternmost mountain group of the Coast Ranges is built.

The rocks in this belt are chiefly of marine sedimentary origin and consist in the main of sandstone and shale. They are in many places such as to indicate a shallow-water or brackish-water origin, and lignitic seams are very characteristic.

The Eocene of the southern portion of the Diablo Range was described by F. M. Anderson, in his first paper[b] relating to this region, as made up of three members, namely, the Avenal sandstone at the base, the Kreyenhagen shales in the middle, and the Domijean sands at the top. The first two of these names were applied to the two members of the Eocene along Reef Ridge in the southern half of the Coalinga district. North of that region those members were correlated with the beds which have been above described as the upper concretionary sandstone and the overlying purple-shale member of the Chico (Upper Cretaceous). The third of these names was applied to

[a] Geol. Survey California, Paleontology, vol. 2, 1869, preface, p. xiii.
[b] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, pp. 162 et seq.

the Eocene sandstone near the Domengine ranch, just north of the Coalinga district, this sandstone being considered to represent an upper sandstone zone. In the present paper this sandstone is treated as the upper portion of the lower member, which is regarded as the correlative of the lower member in the southern part of the listrict. Although it may prove advisable to retain one or two of these names in future, the name Tejon formation is used in the present paper to include the whole succession of beds, for the sake of simplicity and to avoid confusion.

DISTRIBUTION AND LOCAL CHARACTER.

There are three separated areas in which the Tejon is exposed, one in the oil field north of Pleasant Valley, one on the eastern border of the Alcalde Hills just west of Coalinga, and the other along Reef Ridge. Between the Alcalde Hills and Reef Ridge it is covered up, as is the Cretaceous below, by the overlapping Miocene beds.

TEJON NORTH OF PLEASANT VALLEY.

In the northern region the Tejon is typically exposed in the hills directly north of Coalinga, in the vicinity of the camp called Oil City. The formation has a thickness of at least 1,850 feet where most completely exposed on the flanks of Joaquin Ridge, comprising a lower sandy and clayey member 850 feet thick and an upper organic shale member at least 1,000 feet thick.

The beds are markedly unconformable with those of Miocene age above, the unconformity being well displayed in the hills 8½ miles north of Coalinga and near the point pictured in Plate V, *B*. There the low-dipping and comparatively little-disturbed Vaqueros (lower Miocene) sandstone rests on the highly tilted, overturned, and fractured shale of the upper part of the Tejon. The unconformity is likewise evident in other portions of the hills, yet in places there is little variation in dip between the two formations, and the relation might be mistaken for a conformity if the contact were only locally observed. This fact illustrates the local nature of the phenomena in this region. Beds that were violently disturbed in one locality before the deposition of later sediments upon them may have been left comparatively little disturbed a short distance away, and little reliance is to be put in apparent conformities resulting from harmony in angle of dip between two formations.

The basal clay zone of the Tejon and its relation to the Cretaceous beds have already been mentioned in connection with the purple-shale member of the Chico. This zone comprises a thickness of about 700 feet and grades upward into a more sandy zone about 150 feet thick, the two together composing the lower member of the Tejon. The clay zone consists of blackish-gray, fairly compact

fine-grained material and forms a massive, homogeneous deposit with inconspicuous bedding planes. It is on the border line between clay and shale but partakes more of the nature of clay. Considerable fine sand is intermingled, giving much of the clay a gritty character, and there occur occasional layers and lenses of fine sandstone. Tests and impressions of Foraminifera are abundant in this clay, but not so abundant as to cause it to lose its predominantly clayey nature or approach in character the more organic shale in the upper member of the Chico or the upper member of the Tejon of this region. Eocene fossils have been found in the upper portion of the clay zone just north of this district,[a] but as yet there is no certainty whether a small thickness at the base of the zone may not belong to the Cretaceous. At the top the clay grades almost imperceptibly into a very gypsiferous soft clayey sand which forms the upper 150 feet of the lower member. This sandy zone comprises alternating layers of varied character—light-gray sandy clay, dark clay, gray and yellowish sand locally hardened into sandstone, green sand, and hard white calcareous nodules. In places the beds are more hardened than elsewhere and calcareous sandstone predominates, giving the zone prominence. Tejon (Eocene) fossils have been found at a number of points in this zone, both in the sandstone and in the calcareous nodules.

The lower member of the Tejon is traceable southwestward nearly to Los Gatos Creek and is undoubtedly continuous beneath the alluvium with the belt exposed on the west side of Pleasant Valley. It becomes somewhat thinner in that direction and the lower clayey beds are not persistent as a distinct zone.

The upper member of the Tejon as mapped forms a prominent white belt from the region north of Pleasant Valley to and beyond the north edge of the district. Throughout the belt it has an exposed thickness of 400 to 1,000 feet, commonly about 700 feet. The variation is due to the erosion that took place before the deposition of the Miocene. It is probable that the complete succession of beds as originally deposited is nowhere exposed within this region. This member consists chiefly of white, siliceous, hard and brittle, thinly bedded diatomaceous and foraminiferal shale, interbedded with finely fractured, roughly bedded purplish-brown clayey shale, some fine and coarse sand, and thin calcareous shale layers. The typical siliceous shale is exposed in the overturned fold shown in Plate XIII, *A*, on the right in Plate VII, *A*, and with interbedded argillaceous shale in Plate V, *B*. The shale is locally variable in color, assuming different yellowish and reddish tints as the result of staining by petroleum. It contains an abundance of crystallized gypsum, with minor amounts

[a] Owing to the recency of their discovery these have not been listed.

of alkaline mineral matter and sulphur along the intricate fracture planes. Some of the beds are largely composed of gypsum. Dikes of sandstone traversing the beds in various directions are so common as to be characteristic of the formation. An exposure of the shale penetrated by irregular dikes of hard sandstone is shown in Plate VI, *A*.

An analysis of a compact but comparatively soft and less siliceous specimen of chocolate-colored shale from the upper portion of the Tejon, near Oil Canyon, made by R. C. Wells, of the United States Geological Survey, showed the shale to contain approximately 78 per cent of silica. Under a lens it is seen to be composed largely of diatom remains with foraminiferal tests in minor number. The silica content is probably chiefly the product of the siliceous skeletons of the diatoms.

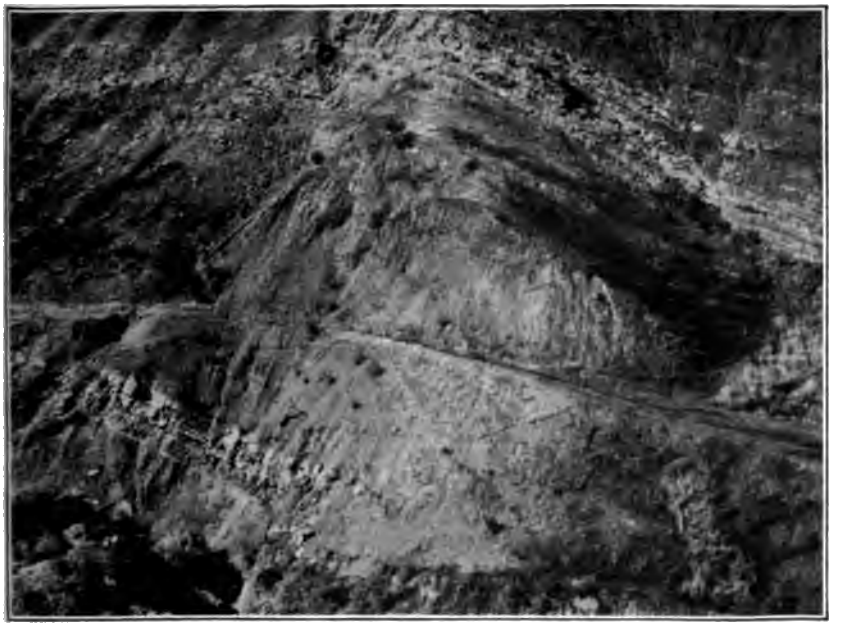
Southwest of Oil City the Miocene beds gradually overlap more and more upon the Eocene, leaving less of it exposed. Owing to lack of exposures of the rocks within 1 mile north of Los Gatos Creek, where it opens out to Pleasant Valley, the lines of contact drawn there are only approximately correct.

TEJON SOUTH OF LOS GATOS CREEK.

The outcrops of Tejon appear again south of Los Gatos Creek in a belt along the base of the foothills facing Pleasant Valley. The formation is conformable in dip with the Chico, and the rocks near the contact are fairly well exposed. The line drawn at the top of the concretionary beds, which are supposed to be at the top of the Chico (Upper Cretaceous), marks the base of some beds of light-yellow and white, soft, gypsiferous sand that are taken as the lowermost Tejon of this part of the area. Within 100 feet above this contact occurs a bed of calcareous sandstone locally greatly hardened and full of typical Tejon fossils. At the two coal mines northwest of Coalinga the yellow sand at the base of the formation is exceedingly gypsiferous and variable in character, and appears to be a shallow brackish and perhaps in part fresh-water deposit. It contains seams of lignite and carbonized wood which in former years have been mined. Above this sand, which has a thickness of about 200 feet, occur thin beds of light-colored, somewhat siliceous hard shale and soft, purplish-brown, gypsum-bearing argillaceous shale composing the upper half of the formation. The latter beds are steeply tilted and fractured and their truncated edges are overlain by Miocene beds with low dip. The unconformity is well exposed in the canyon of the San Joaquin Valley coal mine. At one place 4 miles northwest of Coalinga, within 500 feet above the base of the Tejon, there is exposed a bed of soft diatomaceous shale which probably represents

A. SANDSTONE DIKES IN PETROLIFEROUS SHALE OF THE TEJON FORMATION.

View 15 miles north of Coalinga. Similar dikes are characteristic of this formation. Photograph by Ralph Arnold.



B. PETROLIFEROUS SHALE AND SANDSTONE OF TEJON FORMATION BROKEN BY LOCAL FAULT.

Looking north in canyon of San Joaquin Valley coal mine. Photograph by Ralph Arnold.

part of the siliceous zone toward the top of the formation farther north, although it is not impossible that it occurs within the Miocene beds. Owing to the covering of soil over the undulating ground at the edge of the plain northwest of Coalinga, the thickness and extent of this diatomaceous material, or of the formation as a whole, can not be determined. It may be said, however, that the shale portion of the formation has a thickness in this part of the field of at least 300 feet below the highest horizon that the unconformably overlying Miocene leaves exposed. The Miocene spreads more widely over the Tejon farther to the south until the strike of the Tejon carries it completely beneath the Miocene beds at a point about 3 miles west of Coalinga.

TEJON ALONG REEF RIDGE.

Beds of Tejon age appear again on Reef Ridge, where the same broad lithologic characteristics may be noted—a sandy, frequently yellowish lower portion and a purplish shaly upper portion—although many minor differences are evident in the manner of occurrence north and south of the Miocene overlap. The Tejon beds of Reef Ridge, as compared with those in the northern locality, are in general more indurated and more regular and steeply tilted. The sandstone is more massively and regularly bedded and coarser at the base, and the shale is of different character and more homogeneous. The formation rests uncomformably on what is with little doubt a lower portion of the Cretaceous. An angular unconformity between the Tejon and the Miocene beds above it on Reef Ridge has not been found plainly in evidence along the contact, as it is in the Coalinga field, but an unconformable relation exists between the two formations here as well as farther north, as is shown by the facts that the tilting of the shale beds is in general steeper and the disturbance greater than in the Miocene above; that the Vaqueros (lower Miocene) overlaps at the northwest end of Reef Ridge and rests directly upon the dark shale of the lower portion of the Knoxville-Chico; and that the thickness of the shale of the Tejon exposed along Reef Ridge is varied owing to the overlapping of the Miocene upon different horizons.

The Tejon is exposed typically in the gorges that cut Reef Ridge between Zapato Canyon and Big Tar Canyon. The section (fig. 3) affords a graphic representation of the succession of beds in the latter canyon. The Tejon along Reef Ridge is made up of a basal zone of conglomerate varying in thickness from a few feet to over 100 feet, of a succession of sandstone beds aggregating about 550 feet in thickness, and of an upper shale portion of which a thickness as great as 900 to 1,000 feet is in places exposed. The Tejon becomes thinner west of Zapato Canyon and is not known to outcrop in that direction

west of Jasper Canyon. Toward the southeast the Tejon passes under the overlapping shale of the Santa Margarita (?) formation (upper Miocene) near the extremity of Reef Ridge and disappears entirely. In the region mapped around McLure Valley no evidence of it exists. It

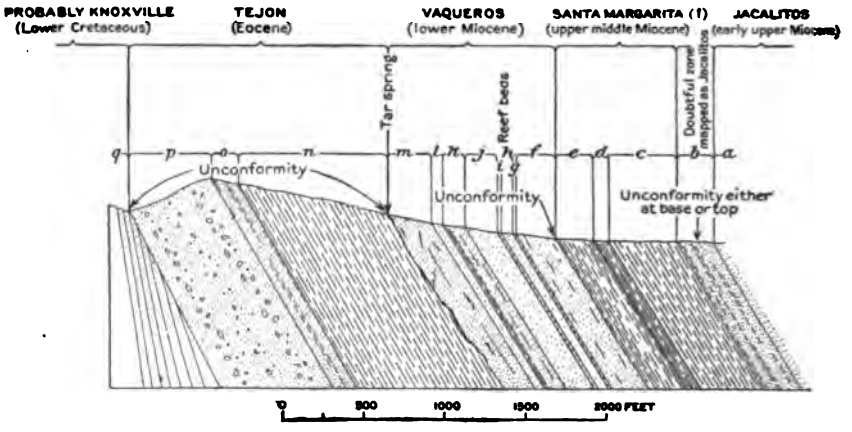


FIGURE 3.—Section of the Santa Margarita (?), Vaqueros, and Tejon formations along the west side of Big Tar Canyon.

	Feet.
a. Gray and brown sand of the Jacalitos formation.	
b. Unfossiliferous brown sand and sandy clay, with occasional layers of hard yellowish-brown sandstone, apparently grading into the Jacalitos above and the Santa Margarita (?) below; of doubtful age, but mapped as Jacalitos	200
Santa Margarita (?).	
c. Soft blue shale at top, grading below into soft brown shale; some brown sand at the top	350
d. Prominent thinly bedded hard white and purplish siliceous shale	100
e. Hard shale similar to that above, grading below into thinly bedded chocolate-colored shale	200
	650
Vaqueros.	
f. Soft gray sandstone and sandy shale	200
g. Prominent massive bed of hard gray sandstone, the upper one of "reef beds"	10
h. Less prominent gray sandstone	75
i. Very prominent massive bed of hard gray sandstone, the lower one of the prominent "reef beds;" this and the associated beds are locally fossiliferous (fossil locality 4627)	10
j. Coarse gray and brownish sandstone	150
k. Thinly bedded hard sandstone and shale, with 20 feet of reddish-brown shale at the base	100
l. Massively bedded, fairly soft grayish-brown sandstone	50
m. Soft grayish-brown sandstone, permeated throughout by veins of petroleum, and with a spring of heavy black oil at base forming tar	200
	795
Tejon.	
n. Thinly bedded purplish, dark grayish brown, and locally light-brown and yellowish siliceous, calcareous, and argillaceous shale	700
o. Grayish-brown sandy clay shale	125
p. Light-gray, yellowish, and brown, locally concretionary and fossiliferous sandstone impregnated with oil	500
	1,325
Total Santa Margarita (?), Vaqueros, and Tejon	2,770

may have been deposited over much of this region and later removed by erosion before the deposition of the Santa Margarita (?), which rests directly on the Cretaceous beds. This subject is discussed in the section dealing with the geologic history (p. 174). Rocks of Eocene age

reappear still farther south on the southwest flank of McLure Valley, in the Devils Den region and beyond.

The sandstone of the Tejon may be easily recognized by the prominent line of peaks that it forms along Reef Ridge a few hundred feet behind the abrupt frontal escarpment produced by the "reef beds." It is for the most part homogeneous, yellowish-gray, medium-grained, oil-stained massive sandstone, locally very hard, especially in the upper portion, but usually fairly soft. In places it is concretionary and weathers cavernous. A characteristic feature of it is that it supports a heavy growth of vegetation as compared with the shale above it. It attains its greatest development in the central portion of its extent and thins toward the two ends of Reef Ridge.

This sandstone contains typical Tejon (Eocene) invertebrate fossils, which place it definitely in this formation and allow its correlation with the fossiliferous sandstone of the Tejon already described from the Coalinga field. At its base it grades into the locally varied conglomerate zone before mentioned, which is taken as marking the base of the formation for the reason that it rests unconformably upon the dark Cretaceous shale in the region of Big Tar Canyon and the head of Garza Creek. Farther west, however, in the vicinity of Canoas and Sulphur Spring canyons, the coarse beds at this horizon rest with apparent conformity and intergradation upon a great thickness of beds of sandstone and soft sandy shale and carbonaceous clay shale that are unlike Cretaceous strata of other parts of the district. It is possible that this underlying terrane is part of the Eocene that is lacking elsewhere along Reef Ridge, but it is mapped for the present with the Knoxville-Chico (Cretaceous). No fossils have been found in it and sufficient work has not been done upon it to determine its relations.

The shale overlying the sandstone of the Tejon is less resistant to weathering and forms a belt of low topographic relief between the line of peaks formed by the lower sandstone and the sharp ridge of the Vaqueros (lower Miocene) "reef beds." This belt is marked by few outcrops and is almost entirely bare of vegetation, except grass and scattered small juniper and oak trees. It is only in the canyons that the rocks of this zone are well exposed, and there they are seen to be chiefly thin beds of purple shale, steeply tilted and considerably fractured and distorted. At the base the beds of this member are almost invariably poorly exposed, but they seem to be somewhat sandy through a thickness of about 200 feet, as if representing a transition from the sandstone of the lower member. Above this transition zone the beds are fine-grained argillaceous and siliceous shale, of a peculiar dark purplish brown, and similar to some of the shale in the upper member of the formation north of Coalinga. Thin laminæ of fine sand are occasionally intercalated. The shale is usually comminuted into fine flakes or locally almost into a powder. It has a black car-

bonaceous appearance in places, this and the purple color possibly being due to the impregnation with petroleum. The cracks in the shale are frequently lined with sulphur. Toward the top the shale becomes yellowish or whitish in places, for example, near and southeast of Big Tar Canyon, and both siliceous and calcareous, the latter variety containing innumerable foraminiferal remains. These beds bring out still more strikingly the resemblance to the shale member north of Coalinga, and indicate that the same horizon is represented in both localities. The thickness of beds exposed between the sandstone of the Tejon and the Miocene varies from place to place along Reef Ridge. The maximum thickness that has been found is in the neighborhood of Canoas Creek, where it is about 1,000 feet.

FOSSILS AND AGE.

LIST OF FOSSILS.

As indicated by the following list, the Tejon formation is well represented by fossils, and in several localities they are in a fairly good or even excellent state of preservation. Among the species collected by the writers within the Coalinga district are the following:

Tejon (Eocene) fossils from the Coalinga district.

Name.	4613.	4614.	4615.	4616.	4617.	4619.	4620.	4621.	4622.	4801.	5013.	5014.
FORAMINIFERA.												
Orbitolites sp. a					×							
ECHINODERMATA.												
Cassidulus californicus F. M. Anderson									×			
PELECYPODA.												
Barbatia morsei Gabb			×				×		×	×		
Cardium breweri Gabb			×					×	×			
Cardium cooperi Gabb					×	×						
Cardium sp. indet			×									
Corbula parilis Gabb			×			×				×		
Crassatellites grandis Gabb	×					×						
Leda gabbi Conrad						×						×
Meretrix gabbi Arnold		×						×		×		
Meretrix hornii Gabb					×		×		×			
Meretrix ovalis Gabb										×		
Meretrix uvasana Conrad			×			×						
Meretrix sp	×											
Ostrea aviculiformis F. M. Anderson										×		
Ostrea idriaenis Gabb		×						×	×	×		
Ostrea sp. indet						×	×					
Ostrea, very large			×									
Petricola? n. sp										×		
Pecten interradiatus Gabb				×							×	
Pecten peckhami Gabb				×								
Placunanomia inornata Gabb			×						×	×		
Septifer dichotomus Gabb							×	×		×		
Solen parallelus Gabb					×	×						
Spondylus carlosensis F. M. Anderson		×			×							
Tellina hornii Gabb					×							
Tellina joaquinensis Arnold										×		
Tellina sp. indet						×						
Venericardia alticostata Gabb								×				
Venericardia planicosta Lamarck						×						
Venericardia sp. (small)			×									
Venericardia sp. indet		×	×									

Tejon (Eocene) fossils from the Coalinga district—Continued.

Name.	4613.	4614.	4615.	4616.	4617.	4619.	4620.	4621.	4622.	4801.	5013.	5014.
GASTEROPODA.												
Actæon sp. indet			×									
Amauropsis alveata Conrad						×				×		
Amauropsis oviformis? Gabb					×							
Cancellaria irelaniana Cooper						×						
Cylichna costata Gabb					×							
Dentalium cooperi Gabb						×						
Fusus remondii Gabb								×				
Galerus excentricus Gabb						×		×	×	×		
Loxotrema turrita Gabb							×			×		
Lunatia hornii Gabb										×		
Lunatia sp. *a*										×		
Nerita triangulata Gabb										×		
Pleurotoma domenginei Arnold						×						
Pleurotoma fresnoensis Arnold						×						
Pleurotoma gulbersoni Arnold						×						
Potamides carbonicola Cooper										×		
Rimella canalifera Gabb		×				×						
Serpulorbis sp. *a*					×							
Spiroglyphus? tejonensis Arnold					×	×						
Tritonidea kreyenhageni Arnold										×		
Tritonium californicum Gabb						×						
Turritella pachecoensis Stanton					×							
Turritella uvasana Conrad		×			×	×		×	×			
Xenophora? sp					×							

4613. About 11 miles north of Coalinga, on west side of sec. 4, T. 19 S., R. 15 E. Top of lower member.

4614. East flank of Alcalde Hills, 3 to 4 miles northwest of Coalinga, along ridge within three-fourths mile of San Joaquin Valley coal mine, in northwest corner of sec. 26 and SE. ¼ sec. 22, T. 20 S., R. 14 E. Prominent medium-grained sandstone bed about 200 feet above contact with concretionary sandstone beds mapped as Cretaceous.

4615. High point on Reef Ridge, about 1 mile south of sharp turn in Zapato Creek and 1 mile east of Sulphur Spring Canyon, in sec. 25, T. 22 S., R. 15 E. Basal conglomerate of Tejon.

4616. Eight miles due north of Coalinga, one-half mile east of Oil Canyon road, and just north of Laval grade, near center of SE. ¼ sec. 20, T. 19 S., R. 15 E. Siliceous shale in upper portion of Tejon.

4617. On southwest flank of Reef Ridge, north of McLure Valley, 2½ miles south-southeast of El Cerrito well, in sec. 27, T. 23 S., R. 17 E. Lower member.

4619. Fifteen miles north of Coalinga, southwest of Domengine's ranch. Sandstone at top of lower member.

4620. Coal mine, 4½ miles northwest of Coalinga, about 1 mile north of San Joaquin mine, SW. ¼ NE. ¼ sec. 22, T. 20 S., R. 14 E. In very gypsiferous variable sand and clay overlying coal seams, 200 to 300 feet above base of formation.

4621. About 5½ miles northwest of Coalinga, on point of hills (elevation 1,100 feet) south of mouth of Los Gatos Creek, in center of NE. ¼ sec. 15, T. 20 S., R. 14 E. In hard calcareous sandstone bed about 150 feet above contact with concretionary sandstone mapped as Cretaceous.

4622. Four miles west-northwest of Coalinga, on top of hill north of road and one-half mile south of San Joaquin Valley coal mine, west of center of SW. ¼ sec. 26, T. 22 S., R. 14 E. Prominent sandstone bed about 150 feet above concretionary sandstone mapped as Cretaceous.

4801. Three miles northwest of Coalinga, at San Joaquin Valley coal mine, in NW. ¼ sec. 26, T. 20 S., R. 14 E. Lower member.

5013. Eight miles northwest of Coalinga, in white siliceous shale at top of Tejon formation, east of center of sec. 25, T. 19 S., R. 14 E.

5014. About 13 miles north of Coalinga, on east side of sec. 29, T. 18 S., R. 15 E., in dark-colored shale just under Miocene oil sand.

OTHER SPECIES COLLECTED.

To the above list of species should be added the following, among others collected by F. M. Anderson [a] in the same region:

FORAMINIFERA.

Cyclammina sp.
Lagena? sp.
Nodosaria p.
Polymorphina sp.
Pulvulina sp.
Sagrina sp.
Vaginulina sp.

ANTHOZOA.

Ellipesmilia granulifera Gabb (4).
Trochocyathus striatus Gabb + Trochosmilia id. (4).

BRACHIOPODA.

Terebratella sp. (2).

PELECYPODA.

Gari texta ? Gabb (4).
Modiola ornata Gabb (3).

GASTEROPODA.

Cancellaria elongata Gabb (1).
Architectonica hornii Gabb (1).
Fusus diaboli Gabb (1).
Fusus martinez Gabb (1, 3).
Morio tuberculatus Gabb (4).
Neverita globosa Gabb (1, 3).

1. Region southeast of Big Tar Canyon.
2. Conglomerate and coarse sandstone near base of Eocene at San Joaquin coal mine and northward to Los Gatos Creek.
3. Sandy beds associated with the carbonaceous strata above 2.
4. North of Los Gatos Creek.

FAUNAL RELATIONS AND AGE.

With the exception of the new Eocene species described by the senior author in Bulletin 396, certain species described by J. G. Cooper and F. M. Anderson from this region, and a few forms that occur in the Martinez or lower Eocene, the fauna of the Eocene of the Coalinga district consists of species heretofore known only from Tejon localities.

The new forms discovered by F. M. Anderson and the writers have so far escaped observation in other localities, but some of them, at least, may eventually be found elsewhere. The species occurring in the Coalinga district and also found at the type locality of the Martinez[b] are as follows:

Cardium cooperi Gabb.
Cylichna costata Gabb.
Dentalium cooperi Gabb.
Leda gabbi Conrad.
Lunatia hornii Gabb.
Morio tuberculatus Gabb.
Tellina hornii Gabb.
Turritella pachecoensis Stanton.
Venericardia planicosta Lamarck (V. hornii Gabb).

According to Merriam[b] *Cardium cooperi* is common in the Martinez and rarer in the Tejon; *Cylichna costata* is rare in the Martinez and

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 164–166.
[b] Merriam, J. C., Jour. Geology, vol. 5, 1897, p. 773.

common in the Tejon; *Dentalium cooperi* is common in the Chico (Cretaceous), Martinez, and Tejon; *Leda gabbi* is common in both the Martinez and Tejon; *Lunatia hornii* is rare in the Martinez and common in the Tejon; the occurrence of *Morio tuberculatus* is questionable in the Martinez; *Tellina hornii* is common in both the Martinez and Tejon; and *Venericardia planicosta* is common throughout the Martinez and Tejon and all through the Eocene for that matter. The *Turritella pachecoensis* from the Coalinga district is much smaller than the typical form from the Martinez. *Pecten peckhami* Gabb extends to the Miocene or even higher.

Of a total fauna of 52 recognizable species in the Tejon of the Coalinga district 10 are species so far known only from the district, 1 has heretofore been known only in the Martinez, 8 are found both in the Martinez and the Tejon (but all these except one are species of which the individuals are as common or commoner in the Tejon than in the Martinez), and 33 are known almost exclusively in the Tejon. It is obvious, therefore, that the bulk of the Eocene in the Coalinga district is of Tejon age, which probably represents a part of the middle Eocene. There is also evidence favoring the correlation of the fauna with that of the Jackson formation of Mississippi.

The faunas of all the localities in the Tejon in the Coalinga district, with the exception of those found associated with the carbonaceous beds west of Coalinga, indicate a marine origin for the deposits. The fauna of the carbonaceous beds (locality 4801, etc.) indicates brackish water at this locality during a part of the Tejon. This agrees with evidence from other parts of the west coast where the middle Eocene is characterized by brackish and even fresh water deposits, usually containing more or less coal. The brackish-water deposits in the Coalinga district are characterized by such species as *Barbatia morsei* Gabb, *Placunanomia inornata* Gabb, *Ostrea aviculiformis* Anderson, and *Potamides carbonicola* Cooper.

The molluscan fauna of the white diatomaceous and foraminiferous shale at the top of the Tejon in the Coalinga district consists of *Pecten interradiatus* Gabb, *Pecten peckhami* Gabb, and *Leda gabbi* Conrad. *Leda gabbi* is a common Tejon species, while *Pecten peckhami* is so far known elsewhere only in the Oligocene, Miocene, and possibly Pliocene. *Pecten interradiatus* is known elsewhere only in shales occupying a similar stratigraphic position to the shales in which it occurs in the Coalinga district. The stratigraphic evidence is strongly in favor of the diatomaceous shales being a part of the Tejon; the faunal evidence is about equally divided; therefore it seems most logical that the rocks in question be assigned to the Tejon, at least until the securing of further and more definite evidence.

Owing to the close resemblance of the shales under discussion to the Monterey (lower middle Miocene) shale of other portions of the

Coast Ranges and to the occurrence in them of the then supposedly characteristic Miocene fossil *Pecten peckhami* Gabb, the former were ascribed to that formation by Watts,[a] Eldridge,[b] and F. M. Anderson.[c] Later,[d] F. M. Anderson withdrew this correlation, suggesting that "the definite assignment of these shales to either the Eocene or the Oligocene in the time scale of California geology * * * must be reserved for further study and for some future time."

IMPORTANCE WITH RELATION TO PETROLEUM.

The diatomaceous and foraminiferal shale forming the upper member of the Tejon is thought to be the original source of the petroleum found in the Tejon and later formations of the Coalinga district. This shale is petroliferous practically throughout its extent in the district, whereas the purple-shale member of the Chico, which is the only oil-bearing zone lower than the Tejon, is present only in the very northern part of the district. The post-Eocene beds are petroliferous where associated with the Tejon. Where it is absent they are dry. In the northern portion of the district the shale forming the upper member of the Tejon is stained with petroleum, but as far as known the formation there does not contain any reservoirs of oil. The oil has migrated upward and collected in vast quantities in the more suitable reservoirs afforded by the Miocene beds. In the southern portion of the district the sandstone of the lower half of the formation is saturated with oil, in places through its whole thickness. The sand has a strong odor, and when a fresh fracture surface is exposed the beds are found to be stained brown throughout. Included layers of shale are stained purple. The wells which are drilled through the shale to this sandstone strike oil in it everywhere in small amounts. The great thickness of the sandstone through which the oil has permeated lessens the probability of its being found in large amounts locally. It is probable that this oil originated in the shale above and became absorbed in the sandstone both above and below. The occurrence of it in the overlying Miocene beds will be mentioned later.

The shale in the upper part of the Tejon contains a large proportion of material of organic origin. The calcareous facies is largely composed of foraminiferal remains, and the hard siliceous beds are very similar to the altered varieties of diatomaceous shale found in other formations in other parts of the State. In places in this district the shale is softer and less altered and may be seen to be composed largely

[a] Bull. California State Min. Bur. No. 3, 1894, p. 65; Bull. No. 18, 1900, p. 136.
[b] Bull. U. S. Geol. Survey No. 213, 1903, p. 307.
[c] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, p. 173.
[d] Idem, 4th ser., vol. 3, 1908, p. 16.

of diatom remains. In the opinion of the writers it is probable that these small marine organisms have been the chief source of the oil.

In other parts of California the origin of the petroleum is ascribed to formations of similar peculiar character, although of different age, and it is a striking fact that all the conditions point to the diatomaceous or foraminiferal nature of the deposits, rather than to the age or other characteristics of the formations, as the determining factor in the original occurrence of petroleum.

GENERAL DESCRIPTION OF THE POST-EOCENE FORMATIONS.

INTRODUCTION.

The Miocene, Pliocene, and early Pleistocene are represented in the Coalinga district by a series of formations that form a group by themselves distinct from the older formations. The first impression received upon viewing the field is that the later Tertiary beds form one continuous succession, and it is therefore natural to take up first a brief review of the whole series before passing to the more detailed descriptions of the different divisions of it, which on closer study are found to be separable from one another.

The periods following the Eocene are here represented by a great series of sandstone, shale, and conglomerate beds, all tilted at about the same angle, having usually similar characteristics, and presenting an appearance of conformity and intergradation. By means, however, of discontinuous fossil faunas, distinguishable lithologic groups, the absence in some places of formations or zones known elsewhere, as a result of erosion and the overlapping of later beds, and the appearance of fragments of older formations within younger ones, several important breaks may be definitely made out, which prove the intervention of periods of time during which land conditions existed over wide areas or locally. The important post-Eocene formations that represent the epochs of submergence of the land in the area now occupied by the Coalinga district are the Vaqueros (lower Miocene), the Santa Margarita (?) (upper middle Miocene), the Jacalitos (early upper Miocene), the Etchegoin (late upper Miocene), and the Tulare (Pliocene and lower Pleistocene) formations. The Tulare formation is probably in large part of different origin from the others, but is similar to them in the general features of its appearance. These formations are all united into one series in the monocline dipping down the east flank of Joaquin Ridge in the northern part of the district, and again in the monocline dipping away from Reef Ridge in the southern portion, but the character of the series is not entirely the same in the two regions.

DESCRIPTION OF THE SERIES IN THE NORTH.

In the northern part of the district the base of the Miocene-Pliocen is formed of coarse and fine oil-impregnated sands unconformabl overlying the whitish and purplish petroliferous Eocene (Tejo shales, these sands being overlain by prominent sandstone beds (th "reef beds"), a prominent zone of white siliceous shale (the "indic tor"), and soft sand up to the base of a zone of bluish-gray and vari gated clay, sand, gravel, and serpentine detritus locally known as th Big Blue. Up to this point the beds are fossiliferous, have a thickne of about 550 feet, and are mapped as Vaqueros (lower Miocene). T Big Blue has a thickness of about 300 feet and is nonfossiliferou It corresponds in stratigraphic position to the Monterey shale (midd Miocene) of regions nearer the coast, but nothing has been discover to indicate that it may belong to that formation. It is overlain b a thickness of about 175 feet of sand, sandstone, and conglomera beds full of immense oysters, barnacles (*Tamiosoma*), scallop she (*Pecten*), and other fossils. These fossiliferous beds will be referred t as the *Tamiosoma* zone. They are overlain by 400 to 500 feet sand and gravel beds up to the base of a very prominent gravel zon full of petrified wood. The beds from the base of the Big Blue u to this point are mapped as the Santa Margarita (?) formation (upp middle Miocene). The gravel zone with fossil wood forms the ba of a succession of sand, sandstone, gravel, and clay beds extendin up to the base of a prominent zone of bluish-gray sand beds havin near their base a rich fossil bed, the *Glycymeris* zone. The successio of beds up from the base of the fossil-wood gravel zone to this poin has a thickness of about 1,600 feet and is mapped as the Jacalit formation (early upper Miocene). The fossil bed (*Glycymeris* zone and bluish sands immediately overlying grade upward into sand an clay beds, the whole forming a thickness of about 1,700 feet, whic is mapped as the Etchegoin formation (uppermost Miocene), and thi finally is overlain by poorly exposed coarse gravel deposits, whic are mapped as the Tulare formation (Pliocene-lower Pleistocene) The total thickness of the succession in the Coalinga field thus out lined is about 4,600 feet, exclusive of the Tulare formation, whic can not be measured in this portion of the district.

DESCRIPTION OF THE SERIES IN THE SOUTH.

In the southern part of the district the basal portion of the Miocen Pliocene series consists of about 700 to 900 feet of steeply dippin hard sandstone and conglomerate beds forming the face of Re Ridge. These overlie, with an important though usually not apparen unconformity, the shale of the Tejon (Eocene) and are locally petroli erous. At the summit they grade into softer beds which are ove

lain by hard siliceous shale. Up to this shale the beds are fossiliferous and are mapped as the Vaqueros formation. The overlying shales are hard and whitish, form a prominent zone varying up to 1,200 feet in thickness, and are mapped as Santa Margarita (?), although only tentatively referred to that formation. These shales are overlain by a great succession of beds of sandstone, shale, sand, clay, gravel, and conglomerate of many varieties, having a thickness as measured in a section south of Big Tar Canyon of about 9,500 feet. This succession is divided on the map, on the basis of criteria to be discussed later, into three approximately equal divisions corresponding to the formations in the north, namely, the Jacalitos (early upper Miocene), Etchegoin (uppermost Miocene), and the Tulare Pliocene-lower Pleistocene). The total thickness of the Miocene, Pliocene, and lower Pleistocene series measurable in the above-mentioned single section is over 11,000 feet.

PREVIOUS CORRELATION.

In his paper entitled "A stratigraphic study in the Mount Diablo Range of California,"[a] F. M. Anderson adopted a classification of the Tertiary rocks in the hills around about Pleasant Valley, where Coalinga is situated, which in the light of more detailed studies has required some modification. To avoid confusion, an outline will here be given of the changes that it has been found necessary to make.

The white and brown shales in the Coalinga field that are in the present report mapped and described tentatively as the upper portion of the Tejon (Eocene) were very naturally considered to be "Monterey" (middle Miocene) by F. M. Anderson, owing to their resemblance to the well-known shales of that formation, and they were so described. The lower Miocene beds were considered to be lacking. The series of strata unconformably overlying the shales and extending nearly up to the fossiliferous beds, here referred to as the *Glycymeris* zone, were described by him as a stratigraphic unit under the name "Coalinga beds," and as upper Miocene in age. The thickness of this series he gave as varying from 2,180 feet 10 miles north of Coalinga to 1,556 feet 10 miles farther north, and to 1,490 feet 3 miles west of Coalinga. As will be discussed more fully in connection with the different formations, this series of strata has been found to be divided into several portions separated by unconformities and representing different periods of the Miocene. At least two of these portions correspond definitely to well-known formations in near-by portions of the State. The accompanying diagram will illustrate the classi-

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 174 et seq.

fications of the strata in the hills north of Coalinga adopted in the present report and by F. M. Anderson in the paper quoted:

Diagram of the middle Tertiary column north of Coalinga.

(Not drawn to scale.)

Present report.	Paper by F. M. Anderson.
Etchegoin (uppermost Miocene).	Etchegoin (Pliocene).
Unconformity	Unconformity
Jacalitos (upper Miocene).	
Unconformity	
Santa Margarita (?), including Big Blue (possibly Monterey) at base (middle Miocene).	Coalinga (upper Miocene).
Unconformity	
Vaqueros (lower Miocene).	
Unconformity	Unconformity
Tejon (upper part) (Eocene).	Monterey (middle Miocene).
	Temblor [= Vaqueros] (lower Miocene) absent here, but occurring in Kreyenhagen field.

The lower beds of the Miocene series, namely, those associated with the "reef beds," are equivalent to those described by F. M. Anderson in the Kreyenhagen field as the "Temblor beds" (lower Miocene), which are themselves equivalent to the widespread Vaqueros sandstone (lower Miocene) of the California Coast Ranges. This portion of the series north of Coalinga contains at several different horizons good faunas characteristic of the lower Miocene.

The middle portion of the series is unconformable upon the lower portion and contains rich fossil beds which have been referred to as the *Tamiosoma* zone. The fauna of these beds is typical of the Santa Margarita (upper middle Miocene) formation, well known in the Salinas Valley region. The Big Blue, which occurs below the *Tamiosoma* zone and which has been included at the base of the Santa Margarita (?) formation in the mapping, may possibly represent in part another well-known formation, the Monterey (middle Miocene), or may be part of the Vaqueros.

The upper portion of the series makes up an unconformably overlying, for the most part nonfossiliferous formation of upper Miocene age, the equivalent of a portion of an important succession of strata occurring well developed and with characteristic fauna in the southern portion of the Coalinga district, where the name Jacalitos formation has been assigned to it in the present report. The "Coalinga beds" were stated by F. M. Anderson to be lacking in the southern portion of the district.

The series termed the "Coalinga beds" was characterized by four lists of fossil species in the original description. The fossils in three of these lists were stated to come from the "reef bed," which has been shown to be Vaqueros (lower Miocene) in age. Those in the fourth were obtained north of the Coalinga district, from a stratum 400 feet above the "reef bed," in the continuation of the beds here mapped

as Santa Margarita (?). As far as faunal characterization goes the "Coalinga beds" are therefore to be correlated with the "Temblor beds" described by Anderson—that is, with the Vaqueros—and with the Santa Margarita (?). In view of the fact that the series has been found divisible into distinct formations of different ages, for the most part equivalent to formations known elsewhere, the name "Coalinga beds" can not be retained.[a]

THE McKITTRICK FORMATION SOUTH OF THIS DISTRICT.

At most localities along the flanks of the Diablo and Temblor ranges south of the Coalinga district it has not been found possible to separate the post-Santa Margarita (?) Tertiary formations, owing to the facts that they are imperfectly exposed and that they are unusually poor in fossils. These beds are the continuation and at least the partial equivalent of the succession of beds in the Coalinga district which is divisible into the three formations Jacalitos, Etchegoin, and Tulare. The name McKittrick formation has been applied to these beds along the Temblor Range because of their importance as a cartographic and (in appearance) stratigraphic unit in and to the north and south of the McKittrick oil district.[b]

To the south of the Coalinga district the McKittrick formation is distributed over both sides of the Temblor Range along most of its length and forms the whole of the Buena Vista and Elk hills. It is particularly important economically, as its basal members are the productive beds for the McKittrick, Midway, and Sunset oil fields. On the east side of the Temblor Range the formation consists of coarse to fine conglomerates and coarse sands near its base, then a zone of bluish sandy clay, then medium to coarse sands and sandy shales, and at the top a succession of alternating coarse gravel and clay beds. The whole formation ranges from 1,300 to possibly 2,500 feet in thickness. It overlies the Monterey and Santa Margarita (?) unconformably, and is in turn unconformably overlain by late Quater-

[a] Since the preparation of this bulletin there has appeared a paper by Frank M. Anderson entitled "A further stratigraphic study in the Mount Diablo Range of California" (Proc. California Acad. Sci., 4th ser., vol. 3, Oct. 31, 1908, pp. 1–40). In this paper the description of the section given in his former paper is considerably revised. The white shales south and east of Oil City are recognized to be Eocene or Oligocene instead of Monterey (middle Miocene), and the unconformably overlying formation, in which the "reef beds" occur, to be lower Miocene. The application of the term "Coalinga beds" is changed so as to leave out the lower Miocene, which was the most typical portion in the original description, and the Big Blue, which is recognized as possibly representing the Monterey. Two faunal lists characterizing the "Coalinga beds" are given for the type locality north of Coalinga, the first being of the fossils of the *Tamiosoma* zone, which are typical of the previously named Santa Margarita formation, and the second being the same list of fossils given in the former paper as from 400 feet above the "reef bed." The thickness of the revised "Coalinga beds" is given as from 500 to 800 feet between Coalinga and Cantua Creek, which is 20 miles or so north. From this it appears that the intention is to restrict the name to practically the same beds north of Coalinga which are mapped in the present report as Santa Margarita (?) exclusive of the Big Blue. South of Waltham Creek these beds are correlated with a portion of the terrane mapped as the Jacalitos formation in the present report. The thickness of the "Coalinga beds" is stated to be "from 1,000 to 1,500 feet in the field between Waltham Creek and Tulare Lake."

[b] Arnold, Ralph, and Johnson, Harry R., Preliminary report on the McKittrick-Sunset oil region, California: Bull. U. S. Geol. Survey No. 406, 1910.

nary sand, gravel, and alluvial deposits. Evidence of an unconformity within the formation was obtained at one or two points.

VAQUEROS SANDSTONE (LOWER MIOCENE).

GENERAL DESCRIPTION.

The unconformity at the top of the Tejon (Eocene) marks an important lapse of time before the beginning of the Miocene period. In the early Miocene a sedimentary formation was deposited in the Coalinga district that is the correlative of the formation known as the Vaqueros in the region nearer the coast.

The Vaqueros in the area under discussion forms an elongated belt east of the belt of Tejon in the hills bordering the great valley. It has a thickness ranging from about 550 feet in the Coalinga field to 900 feet in the Kreyenhagen field of hard and soft sandstone, shale, and conglomerate, and may be easily distinguished from all the other formations by the protruding tendency of the hard sandstone beds, the "reef beds," in its central portion. These beds outcrop prominently in the northern portion of the district, as shown in Plate VII, *A*, and again in the southern portion assume such prominence as to dominate the landscape on the bold face of the long ridge that is named in the present report Reef Ridge. They are much more resistant to erosion than the soft associated beds, and dipping toward the valley on the northeast at an angle varying from 50° to 80° they form the scarp and double row of pinnacles of Reef Ridge fronting the foothills on that side, as shown in Plate VIII.

An important distinguishing feature of the Vaqueros is that the beds at its base are the chief oil sands of the Coalinga district. (See Pl. V, *B*.) In many places they are saturated and discolored with petroleum. They rest upon the eroded surface of the shale of the Tejon throughout most of their extent, but overlap in the Alcalde and Jacalitos hills upon the Knoxville-Chico (Cretaceous) rocks, thus hiding the Tejon from view. Where such overlapping occurs, the basal beds lose their petroliferous character at a distance from the Tejon.

DISTRIBUTION AND LOCAL CHARACTER.

GENERAL STATEMENT.

There are three different areas along the belt of outcropping Vaqueros beds which deserve description separately owing to the diversity of character assumed by the formation in them. One of these is in the oil field north of Coalinga, a second extends from a point in the Alcalde Hills west of Coalinga to Waltham Creek, and the third is along Reef Ridge. The first two areas are separate. The second and third areas are shown on the map as discontinuous, but

A. "REEF BEDS" OF VAQUEROS SANDSTONE OVERLYING OVERTURNED SHALES OF THE TEJON FORMATION.

Looking northwest across foothills 8 miles north of Coalinga. Taken from hill shown in middle of Plate XIV. Photograph by Ralph Arnold.

Santa Margarita
Indicator
White diatomaceous shale
Main one of "reef" beds
Unconformity
Vaqueros sandstone with gravel, sand clay and shale; Basal beds form oil zone D
Overturned shales of the Tejon

B. DIAGRAM OF PLATE VII, *A.*

"REEF BEDS" OF VAQUEROS SANDSTONE FORMING SCARP OF REEF RIDGE.

Looking south across upper portion of Zapato Creek. Photograph by Ralph Arnold.

it is possible that a narrow belt of Vaqueros is exposed south of Waltham Creek, and that this joins the belt on Reef Ridge in the territory southwest of that shown on the map.

VAQUEROS NORTH OF PLEASANT VALLEY.

In the hills north of Coalinga the formation includes all the beds overlying the Tejon at least as far up in the series as the base of the zone locally well known as the Big Blue, and possibly to the summit of this zone, which is at the base of the *Tamiosoma* zone. The Big Blue is not known to be fossiliferous and presents therefore no definite basis for correlating it, but it is mapped for the present as a portion of the overlying formation (the Santa Margarita?) and the summit of the Vaqueros is placed at its base. The term Vaqueros as here used is thereby restricted to those beds which are known by their fossils as belonging to that formation. These beds have a thickness of about 550 feet.

The lowest bed of the formation is coarse, irregular, pebbly sand truncating the eroded edges of the shale of the Tejon formation. A typical exposure of the basal zone is shown in Plate V, *B*. It is followed above by roughly bedded, hard and soft, both coarse and fine sandstone, sandy shale, and pure shale, with some thin white diatomaceous layers. These basal beds for 100 or 200 feet up are thoroughly impregnated with oil and have a dark-brown color due to staining, a strong odor, and a curious mode of fracturing characteristic of rock that is filled with bitumen. About 225 feet above the base is a hard zone varying from 5 to 15 feet in thickness, made up of several calcareous sandstone layers and a rough mixture of ingredients of different kinds and textures. This zone of hard sandstone forms a prominent outcrop over the summit and down the sides of the hill shown in Plate VII, *A*, just east of the road leading up Oil Canyon, appearing from a distance like a portion of the periphery of a huge wheel. Owing to the tendency of this bed to jut out over the surface of the hills, it was referred to as the "reef bed" by F. M. Anderson in his paper above quoted, and the name is here retained for convenience of reference, but changed to the plural to include the various other hard beds just above and below it.

Similar hard and soft sandstone beds continue to about 425 feet above the base of the formation, where a bed some 10 to 20 feet thick of compact white, diatomaceous, and foraminiferal shale is sharply interbedded. This bed is prominent and so sharply marked off from the associated gray sand that it may be easily traced. It has been referred to throughout the field work as the "indicator," and the name was found so convenient that it may as well be used

here. A good exposure of it is shown as a white outcrop running up the ridge to the right of the center in Plate XIV. The bed is continuous, always in the same relative position, from Oil Canyon to the northern edge of the area shown on the map, beyond which no attempt was made to trace it. Southwest of Oil Canyon it is continuous for a mile or two at least. It preserves its strong individuality throughout in spite of the fact that it changes in character locally from a soft though compact earthy deposit, both massively bedded and finely laminated, as on the east side of Oil Canyon near the point shown in Plate XIV, to hard, thinly bedded white porcelaneous or flinty shale and yellowish calcareous shale, as south of the Laval grade on the hill (elevation 2,024 feet) 8½ miles north of Coalinga in the western half of sec. 21. This bed, where not greatly indurated, may be seen with a lens to be full of diatom remains. It is strikingly similar to the siliceous shale characteristic of the upper Tejon, already described, and of the Santa Margarita(?) formation of Reef Ridge, to be described later. An analysis of a sample of the soft white variety from Oil Canyon made by R. C. Wells, of the United States Geological Survey, showed it to contain 48 per cent of silica.

Above the "indicator" bed soft gray and brown sandstone in thin layers makes up a variable zone about 125 feet thick. This sandstone has been found to contain typical Vaqueros (lower Miocene) fossils, and is the uppermost stratum in which they are found. In the central part of the Eastside field it is overlain by soft, fine grayish-white sand that looks bluish from a distance and is well known to the drillers as the Big Blue. Farther north the highest fossiliferous beds of the Vaqueros are overlain by coarse detrital deposits marking the same zone as the Big Blue. The line for the top of the Vaqueros formation is drawn at the base of the zone, which probably represents an important unconformity.

Southwest of Oil Canyon the Vaqueros beds become much thinner, and within about 2 miles they lose their prominence. In the hills for 2 miles north of the head of Pleasant Valley the beds are largely hidden by recent deposits of soil, alluvium, and gravel, but it is probable that a small thickness of beds, representing a part of the Vaqueros, is continuous. Their presence within a mile and a half north of Los Gatos Creek is doubtfully indicated by certain fossils that have been found (locality 4637).

VAQUEROS IN THE ALCALDE HILLS.

In the hills west of Coalinga the Vaqueros is absent north of the San Joaquin Valley coal mine, with the possible exception of a thin discontinuous zone locally exposed beneath the Santa Margarita (?)

A. VIEW LOOKING SOUTH DOWN AVENAL CREEK.

Showing Avenal Ridge, formed of Cretaceous beds, on the right and the hills of white Miocene shale on the left. Photograph by Ralph Arnold.

B. BED OF SAND DOLLARS IN PEBBLY SAND OF ETCHEGOIN FORMATION.

In Kreyenhagen Hills, between Garza Creek and Big Tar Canyon. Photograph by Ralph Arnold

and Jacalitos formations. South of the coal mine incoherent fossiliferous beds of the Vaqueros formation overlap upon the Tejon and Chico (Upper Cretaceous) beds. They have a thickness of about 500 feet, as they have in the Eastside field. The beds are extremely variable and consist for the most part of incoherent yellowish and gray sand, both coarse and fine. The sand is roughly bedded and has partings and lenses of hard sandstone and of gravel. Fossils are abundant in it, but they are poor and not certain as indicators. The section in figure 8 shows some of the features of the formation in this portion of the district. Westward a capping of low-dipping beds extends over the ridges formed of steeply dipping beds of the Knoxville-Chico. This capping is for the most part only slightly indurated sand, gravel, and clay in irregular deposits and variable colors, such as green, blue, red, etc. A few marine fossils were obtained that point to a lower Miocene age, though they do not prove it. Fossil wood occurs in certain places in these beds, notably on the summit of Juniper Ridge, a few miles north of Alcalde Canyon, and it is thought that they may be in part nonmarine.

VAQUEROS IN THE JACALITOS HILLS.

Between Waltham Creek and the north end of Reef Ridge the Vaqueros has not been recognized, but it may form a belt around the southeastern side of Curry Mountain, through the area tentatively mapped as covered by the Jacalitos formation, and thence continue southward beyond the limits of the mapped area, to join the belt on Reef Ridge.

VAQUEROS ON REEF RIDGE.

The Vaqueros sandstone overlies the shale of the Tejon on Reef Ridge and forms the steep face of the ridge. The beds show a thickening of the deposits of this period southward from the region around Pleasant Valley. They also have undergone a greater amount of induration and form a more conspicuous part of the landscape than the contemporary beds farther north. Their relation to the underlying shale of the Tejon is one of unconformity, although no wide disparity in dip has been observed in the strata of the two formations. There is even an apparent gradation from the shale below to the sandstone above in some places and it is difficult to place the exact contact between the two formations. This difficulty is largely due to the lack of continuous exposures near the contact.

The Vaqueros sandstone is subject to considerable variation from place to place, as will be shown in the accompanying tabulated sections. The formation may in general be divided into three zones, one of comparatively soft beds of sandstone and shaly sandstone at the base, comprising about one-fourth of the total thickness; a second

of hard, fossiliferous beds of sandstone with some conglomerate, making up about half of the formation and producing the prominent outcrops of Reef Ridge; and a third zone similar in thickness and character to the first and grading into soft, fine-grained beds that are poorly exposed and lead the observer to think there is a transition to the shales above, which are described as Santa Margarita (?). Such a transition is not supposable if the correlations that have been made are correct. The third zone is much thicker on Canoas Creek than elsewhere and there makes up half of the formation. The Vaqueros as a whole is thicker in the southeastern than in the northwestern half of Reef Ridge. The thickest section observed was on Canoas Creek, where the formation comprises a thickness of 900 feet. The middle zone is marked by three principal horizons of hard, fossiliferous sandstone and conglomerate beds that stand out in strong relief. The lowest of these "reef beds" and the middle one are about 150 to 200 feet apart, and the middle and uppermost beds 100 feet apart on the average. They vary in relative prominence from place to place, and the exact horizon at which the induration is most pronounced is variable.

The following section, together with figure 3, gives an idea of the character of the Vaqueros formation as it occurs typically exposed along Reef Ridge:

Section of Vaqueros sandstone in Canoas Canyon.

	Feet.
Soft, fine sandstone with large oil seepages; "button beds" at base containing *Scutella*, etc. (locality 4772); overlain by siliceous shale of Santa Margarita (?).	180
Hard and soft, gray and brown stained sandstone with large oil seepages in upper half	300
Massive sandstone beds with thick, very prominent, hard beds at top and at base, the "reef beds;" *Pecten andersoni* bed at base (locality 4771)	100
Sandstone with very prominent hard bed, the *Turritella ocoyana* bed, at base (locality 4770)	200
Fairly hard, thin-bedded sandstone underlain by shale of the Tejon formation	120
	900

FOSSILS AND AGE.

LIST OF FOSSILS.

Throughout the Coalinga district the Vaqueros sandstone is at one horizon or another generally fossiliferous and yields a fauna of many species, sometimes in a fairly good state of preservation. The following species have been found by the writers in or immediately adjacent to the Coalinga district:

Vaqueros (lower Miocene) fossils from the Coalinga district, California.

Name.	4624.	4625.	4627.	4628.	4629.	4631.	4633.	4634.	4635.	4637.	4655.	4667.
ECHINODERMATA.												
Scutella merriami F. M. Anderson												
PELECYPODA.												
Arca obispoana Conrad												
Arca osmonti Dall												
Cardium vaquerosensis Arnold						×						
Chione conradiana F. M. Anderson						×	×					
Chione temblorensis F. M. Anderson		×				×						
Corbicula dumblei F. M. Anderson				×	×							
Dosinia mathewsonii Gabb												
Dosinia ponderosa Gray						×						
Macoma aff. secta Conrad							×					
Macoma piercei Arnold						×						
Metis aff. alta Conrad			×			×						
Mulinia densata Conrad		×										
Mulinia densata Conrad var. minor Arnold		×	×									×
Mytilus mathewsoni Gabb var. expansus Arnold										×		
Ostrea titan Conrad												
Pecten andersoni Arnold						×			×			
Pecten crassicardo Conrad												
Pecten estrellanus? Conrad											×	
Pecten miguelensis Arnold												
Phacoides acutilineatus Conrad						×						
Phacoides (Miltha) sanctæcrucis Arnold												
Saxidomus vaquerosensis Arnold			×			×						
Septifer coalingensis Arnold								×				
Tivela inezana? Conrad		×										
Venus pertenuis Gabb						×						
Yoldia impressa Conrad												
Zirphæa dentata Gabb		×	×				×					
GASTEROPODA.												
Agasoma kernianum Cooper						×	×					
Agasoma santacruzana Arnold						×						
Bathytoma piercei Arnold						×						
Cancellaria vetusta Gabb						×						
Cancellaria andersoni Arnold						×						
Conus owenianus F. M. Anderson						×						
Conus hayesi Arnold												
Crepidula sp						×						
Ficus pyriformis Gabb							×					
Neverita callosa Gabb						×						
Ocinebra topangensis Arnold						×						
Trochita filosa Gabb			×									
Trochita sp. indet						×						
Trophon (Forreria) bartoni Arnold												
Trophon (Forreria) gabbianum F. M. Anderson												
Trophon (Forreria) gabbianum F. M. Anderson var. cancellarioides Arnold												
Turritella ocoyana Conrad	×	×	×			×	×					
Xylotrya sp. a												
CIRRIPEDIA.												
Balanus sp												
CRUSTACEA.												
Branchiolambrus altus Rathbun												

4624. *Turritella* bed, or lower one of "reef beds," in Garza Creek gorge through Reef Ridge; southwest corner of the SE. ¼ sec. 3, T. 23 S., R. 16 E.

4625. Sulphur Spring Canyon, in "reef beds;" sec. 23, T. 22 S., R. 15 E.

4627. The "reef bed" just west of Big Tar Canyon; in north part of sec. 18, T. 23 S., R. 16 E.

4628. Oil sand series, in west fork of canyon west of well 3 miles southwest of Coalinga, sec. 12, T. 21 S., R. 14 E.

4629. Anticline Canyon about 3 miles southwest of Coalinga, in roughly bedded gypsiferous sand overlying fossiliferous Chico; in center of sec. 2, T. 21 S., R. 14 E.

4631. *Turritella* bed on east flank of high hill northeast of Oil City, in the SE. ¼ NE. ¼ sec. 16, T. 19 S., R. 15 E.

4633. *Turritella* bed just about 11 miles north-northeast of Coalinga, below the Big Blue, on ridge in sec. 10, T. 19 S., R. 15 E.

4634. Hill south of well sec. 12, T. 21 S., R. 14 E., about 3 miles southwest of Coalinga.

4635. Bed just below the Big Blue, 1½ miles northeast of Oil City, near the SE. ¼ SE. ¼ sec. 16, T. 19 S., R. 15 E.

4637. Six miles northwest of Coalinga, about 500 feet south of contact of Tejon and Miocene, in center of NE. ¼ sec. 2, T. 20 S., R. 14 E.

4655. About 3¾ miles due west of Coalinga, from prominent sandstone bed about 100 feet stratigraphically above contact of concretionary sandstone (Chico) beds with Vaqueros.

4667. The "reef bed" on Reef Ridge, about 1½ miles east of Jasper Canyon, one-half mile west of 2,700-foot hill 5½ miles south-southwest of Alcalde; 125 feet above Cretaceous; in east-central part of sec. 18, T. 22 S., R. 15 E.

Vaqueros (lower Miocene) fossils from the Coalinga district, California—Continued.

Name.	4764.	4770.	4771.	4772.	4773.	4774.	4775.	4777.	4803.	4859.	4860.	4861.
ECHINODERMATA.												
Scutella merriami F. M. Anderson				×		×	×		×		×	×
PELECYPODA.												
Arca obispoana Conrad									×			
Arca osmonti Dall										×		
Cardium vaquerosensis Arnold											×	
Chione conradiana F. M. Anderson												
Chione temblorensis F. M. Anderson									×		×	×
Corbicula dumblei F. M. Anderson												
Dosinia mathewsonii Gabb									×			
Dosinia ponderosa Gray												
Macoma aff. secta Conrad												
Macoma piercei Arnold												×
Metis aff. alta Conrad										×	×	×
Mulinia densata Conrad									×			
Mulinia densata Conrad var. minor Arnold		×						×				
Mytilus mathewsoni Gabb var. expansus Arnold									×			×
Ostrea titan Conrad	×				×				×		×	×
Pecten andersoni Arnold	×		×	×					×		×	×
Pecten crassicardo Conrad											×	×
Pecten estrellanus? Conrad												
Pecten miguelensis Arnold	×											
Phacoides acutilineatus Conrad									×	×	×	×
Phacoides (Miltha) sanctæcrucis Arnold												×
Saxidomus vaquerosensis Arnold												
Septifer coalingensis Arnold												
Tivela inezana? Conrad												
Venus pertenuis Gabb												×
Yoldia impressa Conrad										×		
Zirphæa dentata Gabb									×			
GASTEROPODA.												
Agasoma kernianum Cooper												
Agasoma sanctacruzana Arnold												
Bathytoma piercei Arnold												
Cancellaria vetusta Gabb												
Cancellaria andersoni Arnold												
Conus owenianus F. M. Anderson												
Conus hayesi Arnold												×
Crepidula sp												
Ficus pyriformis Gabb												
Neverita callosa Gabb									×			×
Ocinebra topangensis Arnold											×	
Trochita filosa Gabb									×			
Trochita sp. indet												×
Trophon (Forreria) bartoni Arnold									×			×
Trophon (Forreria) gabbianum F. M. Anderson									×		×	×
Trophon (Forreria) gabbianum F. M. Anderson var. cancellarioides Arnold												×
Turritella ocoyana Conrad		×										×
Xylotrya sp. a											×	
CIRRIPEDIA.												
Balanus sp	×										×	×
CRUSTACEA.												
Branchiolambrus altus Rathbun										×		

4764. Stone Canyon coal mine, Monterey County, Cal., 40 feet stratigraphically above the coal.

4770. *Turritella ocoyana* bed in Canoas Canyon, 1½ miles southwest of Hugo Kreyenhagen's, NE. ¼ SE. ¼ sec. 32, T. 22 S., R. 16 E.

4771. *Pecten andersoni* bed in Canoas Canyon, 200 feet stratigraphically above 4770.

4772. *Scutella merriami* bed ("button bed") in Canoas Canyon, 600 feet stratigraphically above 4770.

4773. About 8½ miles north of Coalinga, on Laval grade; "oyster bed" of variable sand, just above oil sand at base of Vaqueros.

4774. About 8½ miles north of Coalinga, on hill just east of Laval grade; "button bed" about 100 feet stratigraphically above 4773; NW. ¼ sec. 21, T. 19 S., R. 15 E.

4775. Garza Creek gorge in Reef Ridge, hard sandstone "button bed" 225 feet stratigraphically above 4624; southeast corner of sec. 3, T. 23 S., R. 16 E.

4777. Jasper Canyon through Reef Ridge, 1½ miles southwest of fork of Jacalitos Creek, in hard sandstone and conglomerate "reef beds."

4803. About 8½ miles north of Coalinga, "button bed" 200± feet above Eocene unconformity on Laval grade; SW. ¼ sec. 21, T. 19 S., R. 15 E. (Practically the same as 4774.)

4859. Wagon Wheel Mountain, Devils Den district, Kern County, Cal., dark gypsum-bearing shale 50 feet stratigraphically below "reef bed" or "button bed;" NW. ¼ sec. 36, T. 25 S., R. 18 E.

4860. Same locality as 4859; in hard sandstone "reef bed" or "button bed."

4861. Devils Den district, Kern County, Cal., "reef beds" one-fourth mile south and southeast of Barton's cabin, which is in the NW. ¼ sec. 23, T. 25 S., R. 18 E.

OTHER SPECIES COLLECTED.

To the list of fossils given above should be added the following species, among others, collected by F. M. Anderson[a] from the Vaqueros in the Coalinga district: *Agasoma gravida* Gabb, *Crepidula prærupta* Conrad.

FAUNAL ZONES.

Three distinct fossiliferous zones are recognizable in the Vaqueros section north of Coalinga. The lower one is but a short distance above the base of the formation and is represented solely by *Ostrea titan* Conrad (loc. 4773). The middle zone, that of the "reef beds," is about 225 feet above the base and is characterized by *Pecten andersoni* Arnold, *Arca osmonti* Dall, and *Scutella merriami* Anderson (loc. 4774 and 4803). The upper zone, which lies at the top of the Vaqueros and just below the Big Blue sandy shale, is characterized by a unique fauna, in which occur such forms as *Agasoma santacruzana* Arnold, *Cancellaria vetusta* Gabb, *Turritella ocoyana* Conrad, and several other species. The fauna at locality 4631 is characteristic of the last zone.

FAUNAL RELATIONS AND AGE.

In the Coalinga district the correlation of the sandstone formation, of which the "reef beds" are a part, with the Vaqueros formation of the outer Coast Ranges is based upon the large number of species common to the two. At one point in particular on the northeastern flank of the Temblor Range, near Antelope Valley, in sec. 36, T. 26 S., R. 17 E., a few miles south of the south line of the region under discussion, the "reef beds" contain a typical Vaqueros fauna with such forms as *Pecten magnolia* Conrad, *Turritella inezana* Conrad, *Pecten bowersi* Arnold, and many other typical Vaqueros species. The region from which this fauna comes is believed by the writers to mark an old lower Miocene strait joining the San Joaquin lower Miocene sea with the lower Miocene sea which once covered much of the territory now occupied by the outer Coast Ranges.

The lower Miocene (Vaqueros) formation in the Kreyenhagen field was described under the name "Temblor beds" (lower Miocene) by F. M. Anderson,[b] from its characteristic occurrence farther south along the border of the Great Valley near the Temblor ranch. Owing to the possibility of correlating[c] it with the lower Miocene in the Coast Ranges to the west the name Vaqueros, previously adopted in the literature for the beds of that age, is here used.

The assignment of a lower Miocene age to the Vaqueros sandstone is based upon the general similarity of certain members of its fauna

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 171–172.

[b] Idem, p. 170.

[c] In a later paper (Proc. California Acad. Sci., 4th ser., vol. 3, 1908, p. 39) F. M. Anderson recognizes the correlation of his "Temblor beds" of the San Joaquin Valley with the Vaqueros of the outer Coast Ranges.

to species in the lower Miocene of the Atlantic States and upon its relative position in the geologic column of the Pacific coast. This correlation, first made by Conrad, has, so far as the writers are aware, never been questioned.

IMPORTANCE WITH RELATION TO PETROLEUM.

The Vaqueros beds constitute the principal reservoir for the petroleum in the Coalinga district. The oil enters the formation from the shales of the Tejon formation below and collects most abundantly in certain favorable zones within the formation, chiefly at its base, although permeating locally the whole formation in lesser amounts. The summit of the formation, as mapped, being overlain by the Big Blue, north of Coalinga, it is coincident with the top of the productive zone in the Eastside field. Similarly it is believed that the productive zone in the Kreyenhagen field does not reach higher than the Vaqueros, the formation being there overlain by the impervious shales of the Santa Margarita (?) formation. The relation of the formation to the occurrence of the petroleum is discussed more fully in the description of the developed territory.

SANTA MARGARITA (?) FORMATION (UPPER MIDDLE MIOCENE).

GENERAL DESCRIPTION.

A zone of beds full of fossil oysters and barnacles of very large size runs through the midst of the developed oil territory north of Coalinga, and is well known by those familiar with the field. (See Pl. XII, *B*.) Its fossils show it to belong in the same portion of the geologic column as the formation in the drainage basin of Salinas River, farther toward the coast, that has been named the Santa Margarita by H. W. Fairbanks.[a] This formation belongs in the upper part of the middle Miocene. No fossils have been found in the beds immediately below or above the *Tamiosoma* zone, as the fossil beds referred to may be termed from the typical and restricted occurrence in them of the large barnacle of that genus. But the beds below and above, for a thickness of several hundred feet, are for the present mapped in the same formation with the fossil beds because closely associated with them and because affording no sufficient basis for correlation with any other formation.

The basal portion of the formation so mapped is the zone known to the drillers as the Big Blue, the probable unconformable relation of which to the underlying Vaqueros (lower Miocene) has been pointed out (p. 82). The possible Monterey (middle Miocene) age of the Big Blue has also been mentioned (p. 76). This zone in some portions of its extent presents a very striking lithologic contrast to the *Tamiosoma* zone, which fact, coupled with the fact that it is overlapped by

[a] San Luis folio (No. 101), Geol. Atlas U. S., U. S. Geol. Survey, 1904.

the *Tamiosoma* zone on the west side of Pleasant Valley, indicates that it is a distinct unit. Mapping it alone, however, would have led to too great complexity. If it did originate in Monterey time it can at most represent but a brief fraction of that period.

In the Kreyenhagen field the portion of the series between the Vaqueros (lower Miocene) and Jacalitos (upper Miocene), corresponding to the portion occupied by the Santa Margarita (?) farther north, is made up of nonfossiliferous, hard, largely white siliceous shales, and it can not be stated definitely whether or not they are a continuation of the beds to the north. This shale is similar in lithologic character, mode of occurrence, and stratigraphic position to shale on the southwest side of Waltham Valley toward the head of Jacalitos Creek, a few miles west of the area of the map, and is believed to be a continuation of it. In that region the shale zone is underlain by sandstone beds containing fossils typical of the Santa Margarita, as listed under fossil localities 4805, 4841, and 4842. A similar shale zone is present in a similar stratigraphic position over the typical fossiliferous sandstone beds of the Santa Margarita on the opposite side of the Diablo Range on the slope draining to Salinas River. The siliceous shale of Reef Ridge and McLure Valley is therefore tentatively correlated with the Santa Margarita. Inasmuch as the fossiliferous Santa Margarita (?) beds in the northern part of the district and those underlying the shale zone in Waltham Valley may belong to the same horizon in the formation, it is possible that the shale on Reef Ridge is of later age than the *Tamiosoma* zone in the northern part of the district. The period of geologic time between the Vaqueros (lower Miocene) and Jacalitos (upper Miocene) is thought to be represented only in its later part by the *Tamiosoma* zone and associated beds of the Coalinga field and the siliceous shale along Reef Ridge and McLure Valley, the Monterey formation (early middle Miocene) of the region nearer the coast being wholly or at least in large part lacking.

DISTRIBUTION AND LOCAL CHARACTER.

SANTA MARGARITA (?) IN THE COALINGA FIELD.

The basal part of the formation mapped as the Santa Margarita (?) formation is the zone known to the drillers as the Big Blue. This consists in the central part of the Eastside field of about 300 feet of light-gray fine sand and clay that appear to have a light-bluish tinge, especially when moistened. Farther north other materials enter into this portion of the series, causing it to be one of the most varied zones in the region. No fossils have been discovered in it, and its peculiar features show that it was formed under unusual conditions. (See geologic history, p. 175.) It is recognized in the oil wells as a zone of sticky and frequently tough sand and clay immediately over-

lying the oil sands. Toward the northern edge of the area mapped it becomes coarser and is largely made up of fine-grained, coarse-grained, and bowlder beds composed of serpentine fragments, having evidently been derived from an area of serpentine that was in close proximity. Some of these serpentinous beds are extremely hard and they form prominent buttes colored by the decaying serpentine in a variety of shades of light blue, green, brown, and dark red. A typical row of these buttes is shown in Plate X. This zone of beds continues far northwest of the mapped area as a prominent feature of the hills.

The Big Blue is overlain by the *Tamiosoma* zone, which comprises a thickness of about 175 feet of fossiliferous, fine, medium-grained, and coarse, usually gray sand and minor amounts of conglomerate. This in turn is overlain by 400 to 500 feet of alternating beds of fine sand, sandy clay, coarser sand, and gravel up to the base of the prominent and thick gravel zone considered as marking the base of the Jacalitos. These upper beds are without fossils as far as examined and have little to characterize them. The succession of upper beds of the Santa Margarita (?) formation and the lower Jacalitos beds is shown in Plate XVII.

Toward the southwest the Santa Margarita (?) formation disappears east of Oil Canyon, being overlapped by the Jacalitos. It is not known just where the overlap is, because the beds are poorly exposed and have no distinguishing characters there. Beds of the *Tamiosoma* zone underlie Pleasant Valley toward its head, as shown by fossils obtained at depth in wells near the course of Los Gatos Creek. On the west side of Pleasant Valley a remnant of the *Tamiosoma* zone appears, resting directly and with pronounced angular unconformity upon the Tejon (Eocene) at the San Joaquin Valley coal mine. The traceable area of it is not large enough to allow its separation from the later beds on the map. This is the southernmost point at which the fossils of this zone have been found within the district, and south of it the *Tamiosoma* zone is either absent or hidden by the overlapping beds of later age, which are mapped with the Jacalitos formation. There is present, however, beneath the fossiliferous Jacalitos beds, between the coal mine and Waltham Creek, a zone of bluish and grayish clay, about 250 feet thick, mapped with the Vaqueros of that area, that may possibly represent the same horizon as the Big Blue in the Eastside field, though this is doubtful.

SANTA MARGARITA (?) IN THE KREYENHAGEN FIELD.

The Vaqueros sandstone all along Reef Ridge and the Cretaceous in the Pyramid Hills and around McLure Valley is overlain by a formation of white, purplish, and brownish siliceous and argillaceous shale, having a thickness varying between 50 and 1,200 feet. The

thin, sharp beds of shale dip away from Reef Ridge on its northeast flank, and their upturned edges are exposed in a narrow belt which follows the face of the ridge. This belt is likewise a topographic feature, owing to the resistance of the beds, which produce a line of shoulders or knobs on the small lateral ridges descending toward the foothills. The zone occupied by these shales is well shown in the foreground on the right and all along in front of Reef Ridge to the left in Plate VIII. Southeast of Little Tar Canyon the ridge of the Pyramid Hills, which is entirely composed of the shale, is a still more marked expression of this topographic influence, which is likewise characteristic of the formation elsewhere, as, for instance, along the Tent Hills west of McLure Valley, as shown in Plate XI, *A;* in the peculiar curving line of knolls that circles around the base of the mountain mass at the head of McLure Valley on the northwest; and also in the region of Antelope Valley, south of the area of the map, and in the Waltham Valley, west of it. The features described make this shale formation easily recognizable as a lithologic unit with strong individuality, and in the Coalinga district distinguish its main portion markedly from the Vaqueros (lower Miocene) sandstone below and the soft sandstone beds of the Jacalitos (upper Miocene) above. This shale formation is tentatively correlated with the Santa Margarita. It may be a deep-water equivalent of the coarser sediments in the Coalinga field, which at the north end of the area mapped are of a strikingly littoral nature, or it may be of different age.

Lithologically this formation has strong affinities with the well-known Monterey (middle Miocene) shale, which is widely distributed in the Coast Ranges farther west, and its stratigraphic position above lower Miocene and below upper Miocene in this district corresponds to that of the Monterey shale elsewhere. But no proof is known of the contemporaneity of the two formations, whereas the fossil evidence already discussed indicates a lesser age. The shale is likewise very similar to the shale in the upper portion of the Tejon north of Coalinga. This mutual similarity has led previous observers to class the two together and to correlate both with the Monterey.

Along the greater portion of Reef Ridge no unconformity at the base of the shale is apparent, all the formations being similar in dip. But an unconformity is indicated by the fact that the shale overlaps upon the Vaqueros and Tejon at the southeast end of the ridge and that in the region of McLure Valley it lies directly upon the Cretaceous beds, the Vaqueros and Tejon having either never been deposited or else been worn away. As regards the relation of the shale to the overlying formation (the Jacalitos, upper Miocene), it may be said that no definite line of separation has been found and that in appearance a conformable gradation exists along Reef Ridge, although the pinching out of the white shale and finally the overlap of the Jacalitos beds directly upon the Vaqueros farther to the north indicate that

an unconformity exists. The shale is lithologically distinct from the greater part of the Jacalitos formation, but there is a nonfossiliferous transitional zone of alternating sandstone and shale beds having a thickness of several hundred feet, which may belong to either formation. This has been tentatively included with the Jacalitos in the mapping, the beds to which the name Santa Margarita (?) formation is applied being restricted for the present to the underlying shale.

Near the southeast end of Reef Ridge and along the ridge of the Pyramid Hills northeast of Dudley the shale formation has a thickness of 1,050 to 1,200 feet. It is divided into two main portions, the lower of which consists of harder, more siliceous, and more thinly laminated purple and white shale and the upper of softer, more argillaceous brownish shale. The lower portion is the more conspicuous, constant, and typical; the upper is not so well exposed, is more variable in character and is not definitely separable from the soft sandstone and shale of the formation overlying. The following section is typical of the formation along the face of Reef Ridge at its southeast end, the different zones noted not being sharply separated from each other:

Section of Santa Margarita (?) formation 3½ miles southeast of Big Tar Canyon.

	Feet.
Soft brownish clay shale, poorly exposed, grading above into the fine sandy shale at the base of the Jacalitos formation and below into bluish-purple siliceous shale with occasional hard, more siliceous layers	400
Hard, siliceous, porcelaneous, thinly bedded, lavender-colored but white-weathering shale, with angular and conchoidal fracture into elongated, sharp-edged pieces, and with prominent iron stain throughout along joints, interbedded with occasional soft laminæ	250
Fairly hard, purplish, siliceous and argillaceous shale, finely fractured into needle-like fragments with yellow calcareous concretionary lenses and interbedded porcelaneous layers; overlies the Vaqueros	400
	1,050

The two lower of these three zones differ largely in the proportion of hard beds that they contain, and, as this proportion varies from place to place, they do not form continuous belts distinct from each other. Together they make up the lower portion of the formation according to the division above referred to. The siliceous shale of the lower portion varies in amount of induration from a dull opaque rock that may be scratched with the finger nail to a subvitreous flinty variety that will not be scratched by a knife. It resembles very strongly the altered varieties of the Monterey shale (middle Miocene), that occurs nearer the Pacific coast, and of the shale of the Tejon formation and "indicator" bed of the Vaqueros of this district. Like these its less altered varieties show traces of thickly embedded round dots and flakes that are almost certainly the remains of diatoms, and the shale has the characteristic flaky texture of diatomaceous

A. AVENAL RIDGE AND TENT HILLS, SEEN FROM NORTHEAST ACROSS McLURE VALLEY.

Showing steeply dipping Cretaceous strata on Avenal Ridge, the conical hills of white Miocene shale extending into the distance and the terraced surface of the Jacalitos formation flanking the hills. Photograph by Ralph Arnold.

B. SILICEOUS SHALE OF SANTA MARGARITA (?) FORMATION (MIDDLE MIOCENE) AT HEAD OF McLURE VALLEY.

Looking southeast along contact with underlying, less prominent Cretaceous shale on left. Note surficial overturn and typical vegetation of Miocene shale zone. Photograph by Ralph Arnold.

material. The more siliceous shale seems to be almost entirely made up of the crushed diatom tests. A sample of shale from the middle zone in the locality of the above section contained 86 per cent of silica according to an analysis made by R. C. Wells, of the United States Geological Survey. The shale contains also fish scales and other particles of organic origin, but almost no molluscan remains. The laminæ are locally yellowish and calcareous and similar to the foraminiferal shale of the Tejon.

Southeast of Little Tar Canyon the formation increases in thickness to about 1,200 feet, the increase being mostly in the brownish shale of the upper portion. The base of the formation is approximately at the axis of the anticline of the Pyramid Hills. The shale appears on both sides of McLure Valley, with a general steep dip toward the valley and with little change in lithologic character or thickness.

The northernmost point at which the siliceous shale doubtfully ascribed to the Santa Margarita (?) formation has been recognized in this district is at the northwest end of Reef Ridge. There the white shale forms a thin zone between the underlying and overlying sandstone formations. It has a thickness of only about 50 feet. On the west side of Jasper Canyon the Vaqueros is overlain by hard, brittle, yellowish-brown and black clay shale that may be a continuation of the Santa Margarita (?), but its relations have not been studied. A zone composed in large part of shale continues in the same position in the series at least as far as the main valley of Jacalitos Creek to the northwest. This zone is highly tilted and much broken up.

Southeastward along Reef Ridge the shale thickens gradually and continuously. Southwest of the head of Zapato Creek there is about 200 feet of shale that is divided into two zones of about equal thickness. The lower one is of purplish, brownish, and white siliceous shale, similar to that forming the prominent outcrops of this formation elsewhere. The upper is of purplish and brownish, largely clay shale. This grades at the top into alternating beds of brown sandstone and dark clay shale, which make up a thickness of several hundred feet and which may or may not be a part of the same formation. It is possible that this sandstone and shale correspond to part of the thickness of shale found farther southeast, but, fossil evidence being lacking, the formation is restricted for the present to the beds that are purely shale. The most rapid thickening of the formation takes place between Zapato Canyon and Canoas Canyon. At the latter it is about 650 feet thick and comprises three almost equal zones; the lowest of these is of fine-grained purplish shale of medium hardness that is fractured into fine, needle-like, angular fragments; the middle one is hard, siliceous white shale; and the upper is soft brownish shale.

The same siliceous shale is found south of the Coalinga district, extending along the border of the Great Valley of California. The

thickening of the shale terrane continues from the northwest end of Reef Ridge toward the south until at the Temblor ranch in western Kern County the strata of shale attain the remarkable thickness of 5,400 feet. It is probable that a part of the formation there stands for a period of time not represented by deposits in the region of Reef Ridge and may coincide with a part or all of the Monterey shale (middle Miocene). The thickening of the shale southward probably takes place at its base, the beds in the Coalinga district representing an unconformable overlapping of the upper portion upon the Vaqueros.

FOSSILS AND AGE.

LIST OF FOSSILS.

The Santa Margarita (?) formation, from a point 8 miles north of Coalinga northwestward for a distance of at least 6 or 8 miles, is exceedingly fossiliferous, the principal species being the big oyster *Ostrea titan* Conrad, the big barnacle-like *Tamiosoma gregaria* Conrad, and the scallop shell *Pesten estrellanus* Conrad. The names *Tamiosoma* zone and "big oyster beds" have been locally applied to these fossiliferous strata. The species found in this bed by James H. Pierce and the writers are among the following, which comprise the fauna for this formation in the district:

Santa Margarita (upper middle Miocene) fossils from the Coalinga district.

Name.	4632.	4651.	4766.	4805.	4841.	4842.	4848.
ECHINODERMATA.							
Astrodapsis whitneyi Rémond			×				
PELECYPODA.							
Chione conradiana F. M. Anderson							×
Cryptomya ovalis? Conrad	×						
Dosinia ponderosa Gray	×						
Hinnites giganteus Gray		×	×				
Macoma nasuta Conrad	×	×					
Ostrea titan Conrad	×	×	×	×	×	×	
Pecten crassicardo Conrad			×			×	
Pecten estrellanus Conrad		×	×		×	×	
Solen sicarius Gould	×						
Zirphæa dentata Gabb	×						
GASTEROPODA.							
Trophon (Forreria) carisaensis F. M. Anderson			×			×	
CIRRIPEDIA.							
Tamiosoma gregaria Conrad	×	×	×			×	

4632. At and northwest of San Joaquin Valley coal mine near Miocene-Eocene contact.
4651. *Tamiosoma* zone or "big oyster bed" in canyon between old Standard Oil Company and California Oil Fields Limited camps, sec. 28, T. 19 S., R. 15 E.; 8 miles north-northeast of Coalinga.
4766. *Tamiosoma* zone or "big oyster bed" above Big Blue, NE. ¼ sec. 21, T. 19 S., R. 15 E., west of Peerless Oil property, 9 miles north of Coalinga.
4805. Waltham Valley, 13 miles southwest of Coalinga; oyster bed 2 miles west of Elmer Frame's house; sandstone under shale.
4841. Sandstone next to serpentine, at head of Bray and Secords Canyon, 3 miles south of Waltham Valley.
4842. Sandstone at mouth of Bray and Secords Canyon, south side of Waltham Valley. This sandstone underlies the shale in this vicinity.
4848. Nine miles north-northeast of Coalinga, just above *Tamiosoma* zone or "big oyster bed," one-fourth mile northwest of Peerless wells.

A. ARROYO CUTTING PLEISTOCENE SAND AND CLAY THAT COVER SAN JOAQUIN VALLEY.

On plain east of Kettleman Hills, 2 miles southwest of Tulare Lake. Photograph by Ralph Arnold.

B. FOSSIL PECTEN ESTRELLANUS BED IN SANTA MARGARITA (?) FORMATION, 10 MILES NORTH OF COALINGA.

Part of Tamiosoma zone characteristic of the middle Santa Margarita (?) in the oil field. Note large Ostrea titan at the left. Photograph by Ralph Arnold.

FAUNAL RELATIONS AND AGE.

The fauna of the Santa Margarita (?), though small, is one of the most characteristic that is found in the southern Coast Ranges. The association and abundance of certain unique species such as *Tamiosoma gregaria* Conrad, *Trophon carisaensis* F. M. Anderson, and *Pecten estrellanus* Conrad at once indicate its correlation with the Santa Margarita formation of the Salinas Valley and Carrizo Plain regions. The correlation of the siliceous shale in Reef Ridge with the Santa Margarita is based upon the similar stratigraphic position of these shales to beds on the western side of Waltham Valley, near the mouths of Bray and Secords Canyon, which overlie sandstones at locality 4842, containing the following Santa Margarita fauna:

Mytilus aff. mathewsonii Gabb.
Ostrea titan Conrad.
Pecten crassicardo Conrad.
Pecten estrellanus Conrad.
Tamiosoma gregaria Conrad.
Trophon carisaensis F. M. Anderson.

For a number of years the Santa Margarita formation was believed to be the equivalent of the San Pablo formation of the Mount Diablo region, but the stratigraphic work in the Coalinga district seems to show it to be older. At least it is quite evident that the Etchegoin formation represents at least a considerable part of the San Pablo, and as the Etchegoin lies well above the supposed Santa Margarita it seems likely that the latter is, at least in part, of greater age than the San Pablo.

With the Etchegoin and Jacalitos formations correlated as upper Miocene, it seems most logical to place the Santa Margarita in the upper part of the middle Miocene, thus confining the Monterey to the lower part of the middle Miocene. Such an arrangement would assign the far-reaching post-Monterey diastrophic period to the middle of the Miocene. This classification and correlation is of course more or less arbitrary and necessarily tentative, but it seems to best fit the information now in hand.

IMPORTANCE WITH RELATION TO PETROLEUM.

In the Coalinga field the Santa Margarita (?) formation has an important relation in different ways to the occurrence of the petroleum. In the Eastside field its base is taken as extending down through the Big Blue. This zone caps the Vaqueros formation, or productive zone, and although small amounts of oil and tar are found above its base there is none in commercial quantities. The Santa Margarita (?) is of chief importance there as forming an impervious capping which has held the oil in. In the Westside field the formations are thinner, and sand beds of the Santa Margarita (?)

become part of the productive zone. In the Kreyenhagen field the Santa Margarita (?) formation acts, like the Big Blue, as an impervious capping that keeps the oil confined within the Vaqueros sandstone. The similarity of the shale so mapped to the organic shales that elsewhere have been considered the source of oil suggests the possibility that this formation has given rise to some petroleum, but no evidence has been found to bear out such a supposition.

JACALITOS FORMATION (EARLY UPPER MIOCENE)

DEFINITION AND GENERAL DESCRIPTION.

The formation overlying the shale mapped on Reef Ridge as Santa Margarita (?) consists of alternating beds and zones of both soft and indurated sand, gravel, and clay of many varieties which extend up to the base of the beds mapped as Etchegoin and which form a belt along the southwest side of the Jacalitos and Kreyenhagen Hills. This formation has a thickness that may be conservatively stated as being 3,500 feet. In places it is very fossiliferous, and on both sides of Jacalitos Creek especially there are characteristic exposures containing abundant well-preserved fossils. It forms a unit in the Tertiary series of the Coalinga district, and in order that it may be conveniently so treated it will be referred to in this paper as the Jacalitos formation, owing to the occurrence in it of typical faunas along the creek of that name. The fossils indicate that it originated in upper Miocene time and that it is chiefly marine. In part, however, it is probably of fluviatile or lacustrine origin. It is represented in the northern portion of the district by similar beds aggregating a much smaller thickness. Its fauna gives it individuality, and in portions at least of the Coalinga district it is separated from the beds above and below by unconformities. It is probably in part the equivalent of one or more of the upper Miocene formations known in other portions of the State, but until its definite relations to them have been worked out it is necessary to designate it by a local name.

MEANS OF RECOGNITION.

The most important features of the Jacalitos formation by which it may be recognized are its position in the series of Tertiary strata, as outlined on the geologic map and in the text, and the various fossils and fossiliferous zones that it contains. These are listed and discussed below. Owing to its lack of strong lithologic or topographic individuality, the fossils afford the only means which may be relied upon for separating it from the other sandy formations. The fossiliferous beds are frequently much indurated, and they occur at intervals on the surface as hard zones that project like saw teeth and by their resistance protect the beds immediately above and below them. Long parallel ridges are thus produced. The same

feature, however, is characteristic of other formations in this region. The occurrence in all parts of the formation of a great number of sand and pebble beds full of sand dollars is typical of it in the southern portion of the district, though this likewise is a characteristic of the formation above. The usual character of the hills composed of beds of this formation is illustrated in Plates II, *B*, III, and XVII. In a rough way the formation may be distinguished as that portion of the series between the white shale of Reef Ridge below and the major beds of blue sand which throughout the district lie at the base of the formation (the Etchegoin) above it. This upper limit is indefinite, however, owing to the fact that through much of the district the Jacalitos includes a great thickness of blue sand beds in its upper portion.

The blue sand and pebble beds are a striking feature of the Jacalitos and Etchegoin formations in this district. The blue color is due to a thin coating over the individual grains. An analysis of this coating made by R. C. Wells, of the United States Geological Survey, indicates that it is probably vivianite. Its appearance suggests that it might be of similar origin to the blue color frequently noticeable in tuffaceous sands, notably in andesite tuffs of Nevada, and that it might be a product of the decomposition of the minerals of a tuff, but it is believed that the color is of entirely different origin in these two types of deposits.

From its locality of typical occurrence in the Kreyenhagen and Jacalitos hills the Jacalitos formation extends southwestward into McLure Valley, where it has a similar position above the shale of the Santa Margarita (?) formation. Toward the northwest it reaches into the interior of the Diablo Range in the depression formed by the Waltham syncline and toward the north it extends across Alcalde Canyon and into the region around Pleasant Valley. North of Jacalitos Creek it no longer rests upon the shale of the Santa Margarita (?) formation, those beds being lacking, and north of Alcalde Canyon the Jacalitos ceases to be completely represented. The question of the relations of the beds of this age in the northern and southern portions of the district is complex and can be decided only on the basis of detailed paleontologic evidence, aided by study of the structure. Lithology fails almost entirely to be of service. The formation will be discussed separately for the areas lying to the south and to the north of Alcalde.

STRATIGRAPHIC RELATIONS.

The Jacalitos formation in the Kreyenhagen field is unconformable with the shale mapped as the Santa Margarita (?) formation, as may be seen at the northwest end of Reef Ridge, where that shale becomes

lost. Along the greater portion of Reef Ridge, however, a definite appearance of unconformity has not been found, and the line between the two formations is therefore drawn arbitrarily for the present where the beds that are predominantly shale give place above to sandy beds. Toward the head of Zapato Creek and thence westward is a succession of several hundred feet of alternating beds of brown sandstone and dark shale above the siliceous shale of the Santa Margarita (?) formation. These beds are mapped with the Jacalitos, tentatively, it being uncertain to which formation they properly belong.

In the northern part of the district the Santa Margarita (?) beds appear conformable with the beds above, but the overlap of the Jacalitos over the Santa Margarita (?) near Oil Canyon proves clearly that the relation is an unconformable one. Owing to the lack of persistence in the lithologic peculiarities or outcrops of the beds and the scarcity of distinguishing characters, such as fossils for different beds in the series between the *Tamiosoma* zone and the Etchegoin formation, it would be a matter of great difficulty to determine at what horizon the unconformity exists. The base of the Jacalitos formation in this part of the district is thought to be represented, however, by a prominent zone of gravel and conglomerate which contains an abundance of fossilized wood and which is fairly constant along the line mapped as the base north of Pleasant Valley. This zone has yielded a tooth of *Pliohippus*, an extinct horse. The writers are of the opinion that the zone represents a period of land in this area during which river or possibly lake gravels were deposited.

The relation of the Jacalitos to the overlying formation, the Etchegoin, is similar, in that the Etchegoin has the same dip and an appearance of conformity with it in most places, but overlaps upon it elsewhere. The line between these two formations is drawn at the base of the beds which overlapped the Jacalitos and were deposited upon the Cretaceous in the White Creek basin.

DISTRIBUTION AND LOCAL CHARACTER.

JACALITOS IN THE KREYENHAGEN HILLS.

From Jacalitos Creek southward the Jacalitos formation affords more complete exposures than elsewhere. The type locality for its fossils is along this creek, near which representative faunas have been collected from different horizons, as shown in the list of fossil localities (pp. 109–111). But the undisturbed monocline that continues the same beds immediately to the southeast in the Kreyenhagen Hills furnishes somewhat better sections of the formation as a whole, which has suffered considerable disturbance along Jacalitos Creek and in the hills to the north. Moreover, in the latter region

the base of the formation does not appear within the area shown on the map and has not been definitely traced.

The following tabulated sections will give the best description of the lithologic character of the Jacalitos formation and its zones. It must be borne in mind, however, that the formation varies from place to place; that any single description applies merely to a single locality; that the different zones noted are not sharply separable, but grade into one another, all containing elements in minor quantity common to the others; and that a great variety of sedimentary beds occur that would necessitate almost endless discussion to describe in detail. Although the formation is thus varied, part of the variation noticeable in the sections may be due to the fact that exposures are not complete and that beds and fossils apparent in one place are frequently hidden in others. It is especially difficult to determine the relative quantitative importance of clay or somewhat compacted shale, for the reasons that the firmer sand beds are better exposed and therefore appear to dominate and that it can not always be determined whether the softer unexposed beds are fine sand or clay.

The following is a section of the Jacalitos along the creek of that name, from the summit of the formation (at the north base of the 1,220-foot hill in the eastern part of sec. 31, T. 21 S., R. 15 E.) to its contact with the prominent Vaqueros beds at a point not shown on the map, about 1½ miles west-northwest of the end of Reef Ridge (in the middle of sec. 11, T. 22 S., R. 14 E.).

Section of the Jacalitos formation on Jacalitos Creek.

	Feet.
Bluish to brownish-gray clay and clayey sand, alternating with light-gray and olive-gray pebbly sand, with occasional hard fossil layers, and with *Pecten estrellanus* zone at base (fossil locality 4647); overlain by blue sand at the base of the Etchegoin	750
Massive beds of buff and olive-gray sandstone and sandy clay interbedded with thin and thick beds of olive-gray pebbly sandstone and gravel, and occasional sandstone layers. Sand dollars are numerous throughout, usually in the pebbly layers. (See fossil locality 4784.) At the base (at the forks of Jacalitos and Jasper creeks) is a bed of dark-brown sandstone containing a rich fauna; top of the big *Trophon* zone (fossil locality 4765)	1,300
Alternating heavy beds of coarse gray and brown sandstone and thin beds of fine sandstone and sand of the same colors, with some beds of gritty olive-gray sandstone and hard fossil layers. Two hundred feet above base is a bed with large *Astrodapsis* (fossil locality 4654), near the base of the big *Trophon* zone	500
Alternating beds of grayish and brownish sand and sandstone with some sandy clay and fossil layers in the sandstone	750
Alternating beds of soft gray and brown shale and sandstone, much tilted and fractured and in part overturned	500±
	3,800±

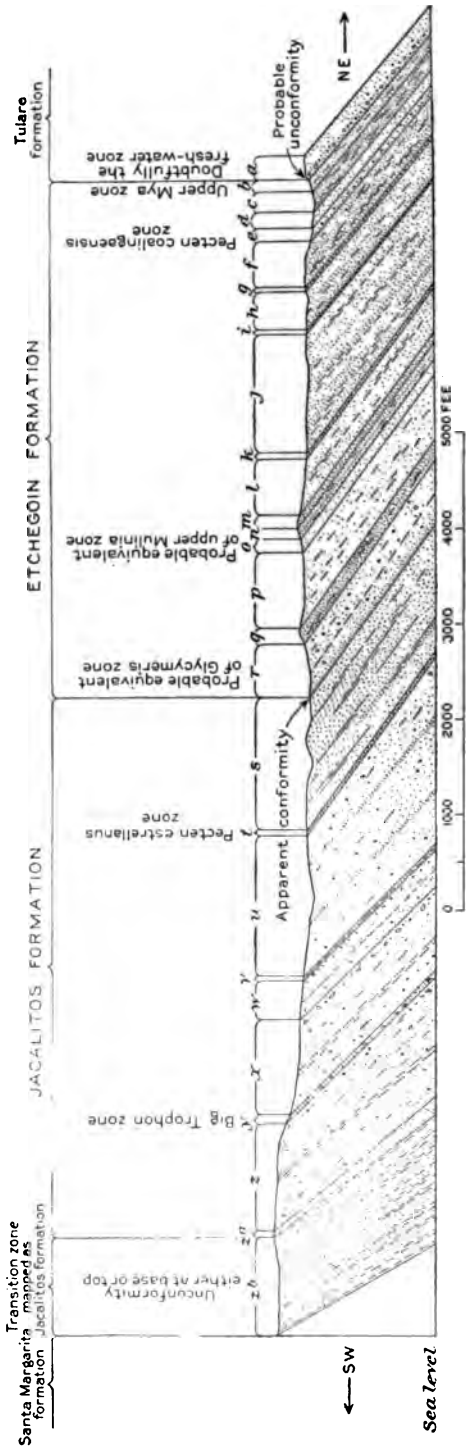


FIGURE 4.—Section of Etchegoin and Jacalitos formations in Kreyenhagen Hills east of Zapato Creek, along line M-M' on geologic map (Pl. I). (See footnote, p. 101.)

The basal portion of this section rests upon the steeply tilted Vaqueros beds that are the continuation of the prominent strata on the face of Reef Ridge. Shale similar to the typical shale mapped as Santa Margarita (?) is entirely lacking, but it is possible that the much disturbed basal zone of this section is unconformable with the Jacalitos and belongs with the Santa Margarita (?) formation. It may be the continuation of the similar thickness of alternating beds of brown sandstone and dark shale overlying the typical shale of the Santa Margarita (?) along Zapato Creek, at the base of the next section to be described.

The middle portion of the Jacalitos formation, in this locality especially, contains large unconsolidated accumulations of fine pebbles, sometimes in thick beds by themselves and sometimes interbedded in thin layers in the sand beds or scattered throughout the sand. These coarse beds are frequently fossiliferous, and sand dollars are especially abundant in them.

The uppermost beds of the above section underlie the lowest one of a number of prominent blue sand beds that are a characteristic feature of the landscape in this district along the belt

of Etchegoin beds. The line of contact between the Jacalitos and Etchegoin formations in the region of the above section is drawn on the basis of this lithologic break and of the characteristic fauna that occurs in a bed just above, at fossil locality 4761. The beds above and below the contact dip with apparent conformity at an angle of about 25°.

The section in figure 4[a] affords a summary description of the Jacalitos formation on Zapato Creek. The alternating sandstone and shale beds at the base of this section, as stated before, may belong more properly with the shale of the Santa Margarita (?) formation and represent a change that gradually takes place toward the northwest in the character of the sediments in the upper portion of that formation. Zone z^b in the section (fig. 4) is well exposed for several

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[a] The letters in figure 4 indicate the following beds:

Tulare.

a. Hill-forming incoherent sand and gravel at base of Tulare.

Etchegoin.

	Feet.
b. Gray sand, sandstone, and clay, with *Mya* bed at top and *Ostrea* bed at base (near localities 4722 and 4744); upper *Mya* zone	100
c. Largely clay and fine sand	150
d. Largely gray sand containing sand dollars and with *Arca* bed near base	100
e. Gray sand and pebbly gravel with locally harder beds of sandstone, forming a rich fossil zone (locality 4705); *Pecten coalingaensis* zone	100
f. Olive-gray fine sand and pebbly sand with thin sandstone layers, interbedded with clay	300
g. Bed of light-blue sand, the highest of the blue-sand zone	10
h. Massive beds of gray sand and sandy clay with occasional thick beds of blue sand	290
i. Prominent zone of pebbly sand with hard layers, *Arca* abundant	30
j. Massive gray, smooth-weathering sand like coarse beach sand, containing many inconstant laminæ of hard brownish-gray sandstone alternating with inconspicuous beds of clay, and with some blue sand	800
k. Prominent bed of massive, olive-gray, compact, irregularly bedded sand	20
l. Minor gray sand and clay beds	350
m. Prominent bed of cavernous-weathering blue sand	50
n. Alternating thick beds of gray sand and bluish clay, with thin layers of brown sandy clay and with two prominent beds of blue sand in middle. This is about the equivalent of the upper *Mulinia* zone	200
o. Prominent blue-sand bed	25
p. Olive and light-gray sand and sandy clay	425
q. Prominent group of blue-sand beds; three blue-sand beds close together forming a hill and associated with massive dark olive-gray sand, pebbly sand, and sandy clay with irregular bedding	150
r. Prominent bed of blue sand at base, with prominent massive beds of olive-gray medium-grained and pebbly sand and minor beds of clay and blue sand above; this is the base of the blue-sand zone and approximately that of the Etchegoin	375
	3,475

Jacalitos.

s. Soft, compact, massive, medium and fine-grained olive-gray and brownish sandstone, with some thin beds of clay shale and sandy shale, and with occasional pebbly beds. Overlain conformably by blue sandstone at the base of the Etchegoin	800
t. Calcareous sandstone with fossils, probably zone of *Pecten estrellanus*	10
u. Sandstone similar to that of *s*, with some hard layers of dark-brown sandstone	700
v. Fine-grained, gritty, white, ashlike shale	15
w. Sandstone similar to that of *s*, with occasional thick beds of cross-bedded pebbly sandstone and beds of sandy shale with flaky texture; at the top a hard bed containing *Pecten*	250
x. Similar sandstone and shale with concretions in sandstone near the top	650
y. Sandstone bed with *Pecten*, *Panopea*, sand dollars, barnacles, etc., the approximate equivalent of the big *Trophon* bed on Jacalitos and Canoas creeks	10
z. Soft, fine and medium grained, massive grayish and buff sandstone and sandy shale with occasional hard layers and pebbly beds; some coarse sandstone beds in upper part full of large fragments of petrified wood	740
z^a. Hard sandstone layers with poorly preserved fossils	50
z^b. Alternating beds of fairly hard brown sandstone and dark clay shale, only doubtfully referable to the Jacalitos. It is underlain, to all appearance conformably, by the siliceous shale of the Santa Margarita (?) and may belong to that formation	600
	3,825
Total Etchegoin and Jacalitos	7,300

miles along the south side of the longitudinal valley of Zapato Creek, along that portion shown on the left in Plate VIII, the contact between this zone and the overlying soft sand zone being marked by the valley. Further work may show that the contact followed by this valley is an unconformable one. The abundant petrified wood in the beds above suggests their equivalence to the beds taken as the base of the Jacalitos north of Pleasant Valley and an origin other than marine. The big *Trophon* zone (*y* in fig. 4) above the fossil-wood beds forms a capping for a longitudinal ridge that extends in front of Reef Ridge on the north side of the valley. To the west of Zapato Canyon, where this longitudinal ridge coalesces with Reef Ridge, beds of the big *Trophon* zone continue to form prominent shoulders on the various lateral ridges that they cross.

Various other hard beds in the middle portion of the Jacalitos formation form similar lines of hills or partially continuous ridges along their strike and may thus be traced for a long distance, but most of them acquire greater induration only locally and give place to other beds as ridge formers after an extent of a few miles. In the hills between Jacalitos and Zapato creeks the middle portion of the formation is especially rich in sand-dollar beds, some of which are of fine gravel and form the most prominent hills. As the section explains, the top of the Jacalitos here as well as on Jacalitos Creek is marked by the overlying blue sands of the Etchegoin. In addition to this easy means of distinguishing between them an important fossil bed, the probable equivalent of the *Glycymeris* zone, may be traced most of the way between these two creeks near the base of the blue sand.

The following is a section along Canoas Creek from the top of the Jacalitos, which is immediately south of the house of Hugo Kreyenhagen, to its contact with the Santa Margarita(?) formation.

Section of the Jacalitos formation along Canoas Creek.

	Feet.
Chiefly grayish sand and soft sandstone, with thick pebbly zone at base containing *Pecten estrellanus* (fossil locality 4767). Overlain by rich fossil bed of locality 4769, at base of Etchegoin	650
Chiefly massive, gray and buff, coarse-grained sand; a prominent bed of friable dark sandstone with *Panopea*, etc., at base	1,000
Similar sand with prominent ridge-forming bed at base	350
Similar sand with prominent bed, the big *Trophon* zone, at base	400
Similar sand with occasional sandstone layers and with prominent sandstone bed at base forming first hill northeast of Reef Ridge	500
Similar sand grading below into sandy shale overlying the Santa Margarita (?) formation	600
	3,500

Between Zapato and Canoas creeks the beds follow low, gently rolling strike ridges and valleys, and although they are soft and not prominently exposed they may be traced by means of the topography and the belts of vegetation. A peculiar feature of the beds is that in several places those which form ridges west of Zapato Creek or part way across to Canoas Creek become transferred to strike valleys, and vice versa, the original tendency in some beds being reassumed farther along their course. This feature is equally characteristic of other portions of the Kreyenhagen and Jacalitos hills and of the overlying Etchegoin formation as well. This inconstancy frequently makes the task of tracing the beds a puzzling one.

The Jacalitos beds show every appearance of being conformable with the shale of the Santa Margarita (?) formation in the region of the foregoing section. The shale and sand 600 feet thick given at the base of the section are thought to be equivalent to the basal zone already discussed in connection with the previous sections. Northeast of the valley occupied by this zone there extends a prominent ridge formed by a succession of beds, containing numerous hard fossil layers and comprising a thickness of about 1,200 feet, that are the continuation of the similar beds found in the previous sections. In the central portion of this fossiliferous zone is the big *Trophon* zone.

The top of the Jacalitos here as elsewhere is marked by a typical association of fossils in the summit beds, and the usual basal Etchegoin fauna, which is of somewhat different character, occurs in the beds just above. The line is marked here as in the previous instance by being at the base of the blue-sand beds of the Etchegoin.

Southeast of Canoas Creek the Jacalitos formation preserves a character and a thickness very similar to those given in the above sections. The fossiliferous sandstone beds become more indurated, so that they stand out like sawteeth on the summits of longitudinal ridges most of the way to Big Tar Canyon and form very pronounced features of the landscape. As this canyon is approached the beds assume steeper and steeper attitudes until they dip uniformly at angles varying between 50° and 60°. The chief new feature of the formation in this region is that some of the sand and pebble beds in its higher portion have the blue color characteristic of the basal beds of the Etchegoin. Confusion is thus introduced into the separation of the two formations, but the same paleontologic criteria used in distinguishing between them elsewhere still hold good here. In the neighborhood of Garza and Big Tar creeks the zone of blue sands extends down over 800 feet into the Jacalitos, whereas farther southeast, as shown in the next section, it extends to a still lower horizon, the lowest at which it has been found anywhere. The exact similarity of the beds above and below the contact of this formation with the Etchegoin overlying, taken together with their perfect angular conformity, is almost con-

clusive evidence of their actual conformity and continuity. It is believed that here where these formations are so complete they form an unbroken sequence, whereas farther to the north, where the thicknesses are very much reduced, they are separated by an unconformity.

Southeast of Big Tar Creek the beds begin to lose in prominence and to form nearly uniform rolling hills of soft sand with few large exposures. The dip in this region becomes uniformly about 60°. The following section shows the character of the formation at about the farthest point southeast in the Kreyenhagen Hills at which a section of any completeness can be obtained from the surface exposures. Beyond this point the hills still preserve traces of their longitudinal strike structure, but much more faintly than farther northwest, and most of the beds are soft and weather out into surface sand that hides them. Fossils are only rarely to be found and there is next to no basis for separation between zones or formations.

Section of the Jacalitos formation on north side of Reef Ridge, 3½ miles southeast of Big Tar Canyon.

	Feet.
Dark-gray sand, with about 20 feet of light-blue sand at base	120
Olive-gray sand, with light-blue sand at base; the basal portion is probably the main *Pecten estrellanus* zone found 1 mile northeast	350
Fine shaly yellowish-gray sand, with whitish-gray and dark-gray layers interbedded and some bluish pebbly sand; the lowest blue sand is at base	720
Compact medium-grained to coarse gray sand, like beach sand	275
Olive-gray speckled sand and soft sandstone, with appearance of a pepper-and-salt mixture	275
Interbedded fine and medium grained grayish, whitish, and yellowish sand and speckled sand like the last, with some clay layers	600
Fine and medium grained reddish, yellowish, and grayish sand and soft sandstone, with white sandy clay at top and coarse pebbly sand 300 feet below top; grading at base into soft whitish-gray sandy shale	1,200
	3,540

JACALITOS IN THE REGION OF M'LURE VALLEY.

The Jacalitos is worn off over the summit of the Pyramid Hills anticline, but reappears on its southwestern flank in the northwestern portion of McLure Valley, dipping under the alluvium of the valley floor. The descriptions of the formation already given apply to it as it appears in this region. The exposures are in general poor.

Around McLure Valley the more siliceous beds of the Santa Margarita (?) grade upward into 500 to 600 feet of soft brown argillaceous shale and some sand that reach up to the base of a prominent bed of brown sandstone which is mapped as the base of the Jacalitos. Further investigation may prove the upper portion of the succession of beds here included in the Santa Margarita (?) formation to be equivalent to the transitional shale and sandstone zone appearing at the base of the Jacalitos sections in the northern part of the Kreyenhagen Hills. Along the north side of McLure Valley and the valley

of Avenal Creek the hard, prominent sandstone bed mentioned extends continuously with a dip toward the valley of about 50° and forms a succession of eminences. Along the southwest side it is not so easily traceable. Above this bed comes a succession of soft beds, chiefly of sand, aggregating about 2,600 feet in thickness up to the base of a prominent bed of soft, coarse blue sandstone like that in the upper portion of the Jacalitos and the lower portion of the Etchegoin, previously noted. This sandstone influences the topography by forming hills as much as 100 feet high. About 1,000 feet stratigraphically above it a similar blue bed makes its appearance in the axis of the plunging syncline near the head of McLure Valley, and continues to outcrop for 1 or 2 miles on either side of the fold along lines diverging from the axis. The lower of these two beds is the base of the blue-sand zone, and the strata between are in part of inconspicuous blue-sand beds. The upper bed is assumed as the approximate summit of the Jacalitos formation and is so mapped. The thickness of the formation so delimited is about 3,600 feet, the same as in the Kreyenhagen Hills, and the blue-sand zone has about the same thickness as in the section last given.

JACALITOS IN THE JACALITOS HILLS.

Passing now back to the region of the type locality for this formation, we may take up its occurrence from that locality northward. In the Jacalitos Hills a plunging anticlinal fold breaks up the regular monoclinal structure in the lower half of the formation, causing it to be folded at various angles and in various directions and to spread over a wider area toward the west. The base of the formation is not known to appear within the area mapped.

The regularity of dip of the upper half of the formation, however, is little disturbed and a continuous section is well exposed. This portion affords a great many excellent fossils, the principal zones of which are traceable directly into those south of Jacalitos Creek, and in general the formation here is similar to the occurrences already described. It preserves the general character of a great thickness of soft beds that are chiefly of sand and that vary rapidly both horizontally and vertically into all gradations of texture from that of clay to that of pebbly gravel. The beds are in places very gypsiferous, and yellow deposits of sulphur occur along the joint cracks. In the southern part of the Jacalitos Hills the lowest zone exposed in the axis of the anticline corresponds to the central portion of the zone of pebbles and sea urchins found on Jacalitos Creek.

In the central part of the hills, 700 to 800 feet below the top of the formation, there outcrops a prominent bed several feet thick of white, hard, gritty, very brittle, and much fractured shale somewhat similar to the hard variety of the "indicator" bed in the Vaqueros,

north of Coalinga. It may be volcanic ash. It occurs at a horizon just above that of *Pecten estrellanus* in the uppermost zone in the section on Jacalitos Creek given above. The bed extends northward a little more than a mile from the northwest corner of sec. 31, T. 21 S., R. 15 E., following the east side of the road from Alcalde to Jacalitos Creek, and there becomes lost. It seems to be continued by a bed of white shale found at a similar horizon on the west side of the 1,900-foot hill southeast of Alcalde. It is underlain with fairly sharp contact by very fossiliferous fine clayey sand and medium-grained sand full of large pectens, cardiums, panopeas, etc., and overlain very sharply by gritty and gravelly sand full of sea urchins (fossil localities 4638 and 4639). This upper contact is wavy, the sand bending down a foot or two into concavities in the surface of the shale in places, but it is not thought that the contact represents an unconformity. The inequalities were more probably original variations of the surface of deposited material due to currents or other local causes.

The succession of beds exposed on the western flank of the 1,900-foot hill 1 mile southeast of Alcalde, east of the road leading southward from Alcalde toward Jacalitos Creek, comprises about 1,600 feet of sand, clay, gravel, and fossiliferous sandstone up to the base of the blue beds which mark the Etchegoin formation. Locally on the flank of this hill the beds have a slight stain resembling that due to the presence of oil. West of the road above mentioned the Jacalitos beds are chiefly sand, with some clay and gravel and with fossils. They overlap upon the steeply tilted Cretaceous strata and are warped into a number of low plunging folds. Still farther west the Jacalitos overlaps over a wide extent of country in the Waltham syncline, along which it has been traced 6 miles west of the area shown on the map, along Jacalitos Creek as far as the road to Stone Canyon.

JACALITOS IN THE ALCALDE HILLS.

North of Waltham Creek the Jacalitos formation has not the great thickness that characterizes it throughout its extent in the south, being only about 800 feet thick. This thinning northward is very rapid in the immediate vicinity of Waltham Creek as it is in the Etchegoin formation as well, indicating that the lower portion of Alcalde Canyon follows a line that has been an extremely important locus of orogenic movements. It has not been determined whether the change that takes place in the Jacalitos is a constant thinning affecting all the beds of the formation, or whether it is due to the absence of some large parts of the formation, owing either to their not having been deposited north of Waltham Creek or to their having been worn away. It may be that the zones full of fossil wood near the

base of the Jacalitos in the Kreyenhagen Hills and north of Pleasant Valley are the same, but it is believed that the area north of Waltham Creek was land during the earlier part of Jacalitos time and that the lower portion of the formation was not deposited there.

The formation over the area of the Alcalde Hills retains the general character of the beds to the south. It is a varied formation of incoherent yellow, brown, and gray sand, sandstone, clay, and gravel, locally containing abundant fossils. The typical fauna of the lower part of the formation in the type locality along Jacalitos Creek is not present. The beds are evidently of near-shore origin, being in many places roughly bedded, cross-bedded, and varied. They are full of gypsum. The formation is described in connection with the section (fig. 4). The base, as mapped, is a fossiliferous bed containing *Pecten estrellanus*, etc., which is traceable southward from the San Joaquin Valley coal mine to Waltham Creek. It is underlain, with an appearance of conformity, by a zone of clay and fine sand about 300 feet thick, which has been mentioned before as possibly belonging to the horizon of the Big Blue (Santa Margarita?), but which is mapped with the Vaqueros. The summit of the Jacalitos formation is at the base of the *Glycymeris* zone, which is the equivalent of the basal Etchegoin as found elsewhere. The beds along this contact do not give evidence of unconformity.

JACALITOS IN THE AREA NORTH OF PLEASANT VALLEY.

The beds in the northern part of the district that have been correlated with the Jacalitos constitute that part of the series on Joaquin Ridge which lies between a prominent basal zone of gravel that outcrops typically on the hill where the tanks are situated above the Standard Oil Company's wells (in the northeast corner of the NW. ¼ sec. 28, T. 19 S., R. 15 E.) and the base of a zone of bluish-gray sand and abundant fossils (the *Glycymeris* zone) outcropping typically on the hill where one tank stands in the northwest corner of the SW. ¼ sec. 34, T. 19 S., R. 15 E. This portion of the series consists of about 1,600 feet of alternating fine gray sand and clay, pebbly and medium-grained sand and sandstone, and gravel. The basal pebbly zone has a thickness of about 150 feet, of which the lower half is a solid layer of pebbly gravel locally hardened to conglomerate and the upper half thinly bedded brown, gray, and, in some places, pinkish sandstone and sand intermingled with pebbles and with occasional shaly layers. This zone contains a great abundance of petrified wood in large fragments and at one place (locality 5015) a tooth of an extinct species of horse was found in it. An opinion as to the possible nonmarine origin of this zone has been expressed above. Owing to the great variety of constituents in these beds and the likelihood of their furnishing further fossils they would

make an interesting subject for detailed study. The prominent basal beds are shown at the right of the center in Plate XVII. The rest of the formation is mostly soft sand, with which hard sandstone and conglomerate layers, pebbly sand, and sandy clay beds are frequently interbedded. The upper 700 feet consists of fine light-colored powdery sandstone, sandy clay, and clay, usually forming a belt of low topography but interbedded with several locally prominent 10 to 40 foot zones of blue pebbly sandstone like that in the Kreyenhagen Hills and in the overlying Etchegoin. The lowest of these blue strata are very conglomeratic and full of large fragments of silicified tree trunks. Impressions of leaves of deciduous trees were found in one of the lenses of clay common in this conglomerate, about 650 feet below the base of the Etchegoin 7½ miles north of Coalinga, on the west side of the SE. ¼ sec. 28, T. 19 S., R. 15 E. No marine fossils have been found in place in the Jacalitos beds north of Pleasant Valley.

FOSSILS AND AGE.

FOSSILS.

Like the Etchegoin above it, with which it is closely allied, the Jacalitos is fossiliferous in many localities in the Coalinga district and adjacent regions, especially in the Waltham Valley, 13 miles southwest of Coalinga. In the upper part of the formation the fossils are usually in a very good state of preservation; in the lower part the original shell has usually been leached out and replaced by other material, and some of the fossils are simply casts.

The following species have been found in the Jacalitos formation in the Coalinga district or in the Waltham Valley:

Jacalitos (upper Miocene) fossils from the Coalinga district.

Name.	4636.	4638.	4639.	4640.	4642.	4644.	4645.	4646.	4647.	4649.	4650.
ECHINODERMATA.											
Astrodapsis jacalitosensis Arnold											
Echinarachnius gibbsii Rémond		×	×		×					×	
PELECYPODA.											
Arca trilineata Conrad				×							
Cardium meekianum Gabb											
Cardium sp. a											
Cardium sp			×								
Chione securis Shumard					×						
Cryptomya ovalis? Conrad		×									
Diplodonta harfordi? F. M. Anderson											
Diplodonta parilis Conrad											
Diplodonta sp. indet	×										
Dosinia jacalitosana Arnold											
Glycymeris sp. indet	×										
Macoma secta Conrad											
Macoma jacalitosana Arnold											
Macoma vanvlecki Arnold											
Macoma sp. a											
Metis alta? Conrad				×							
Metis sp											
Monia macroschisma Deshayes					×						
Mulinia densata Conrad								×			
Mytilus (Mytiloconcha) coalingensis Arnold											

Jacalitos (upper Miocene) fossils from the Coalinga district—Continued.

Name.	4636.	4638.	4639.	4640.	4642.	4644.	4645.	4646.	4647.	4649.	4650.
PELECYPODA—continued.											
Ostrea atwoodi Gabb											
Panopea generosa Gould			×							×	
Panopea estrellana Conrad											
Paphia staleyi? Gabb		×	×								
Paphia jacalitosensis Arnold											
Paphia aff. tenerrima Carpenter											
Pecten estrellanus Conrad				×	×	×			×		×
Pecten crassicardo Conrad					×						
Pecten oweni Arnold									×		
Saxidomus nuttalli Conrad				×				×			
Schizodesma abscissa Gabb											
Schizothærus pajaroanus Conrad		×	×	×						×	
Solen sicarius Gould											
Tellina aragonia Dall											
Thracia jacalitosensis Arnold											
Zirphæa dentata Gabb											
GASTEROPODA.											
Chrysodomus imperialis Dall											
Chrysodomus portolaensis Arnold											
Crepidula princeps Conrad											
Lunatia lewisii? Gould									×		
Margarita johnsoni Arnold											
Melongena sp. a											
Neverita recluziana Petit											
Neverita sp											
Thais crispatus Chemnitz											
Thais kettlemanensis Arnold											
Trophon (Forreria) ponderosum Gabb		×			×		×			×	
CIRRIPEDIA.											
Balanus sp.											
Tamiosoma gregaria? Conrad											
PISCES.											
Fish vertebræ											
MAMMALIA.											
Pliohippus sp. a											

4636. Hill 4 miles N. 85° W. of Coalinga, not far from contact with concretionary sandstone beds mapped as Cretaceous (Chico), on west side of sec. 35, T. 20 S., R. 14 E. Lower beds.

4638. Three hundred feet east of nose of 1,300-foot ridge, three-fourths mile southeast of Alcalde, in center of sec. 24, T. 21 S., R. 14 E. Olive-gray gypsiferous sand overlying white shale bed, about 700 or 800 feet stratigraphically below top of the Jacalitos formation as mapped. Upper beds.

4639. About 2 miles south of Alcalde on south side of 1,548-foot hill, in sand immediately above and below white shale bed, in sec. 25, T. 21 S., R. 14 E. Same horizon as 4638, upper beds.

4640. Near Commercial Petroleum well, 3 miles southwest of Coalinga. Upper beds.

4642. About 20 miles south of Coalinga, in Kreyenhagen Hills. Gray sand 500 feet southwest of top of 1,053-foot hill, four-fifths mile southwest of El Cerrito well, in NW. ¼ SW. ¼ sec. 15, T. 23 S., R. 17 E. *Pecten estrellanus* zone, or upper beds.

4644. Southeast base of 1,300-foot hill, on north side of Jacalitos Creek, just north of old adobe house two-thirds mile above fork of Salt Creek, in center of south side of sec. 31, T. 21 S., R. 15 E. Upper beds.

4645. One mile west of Garza Creek on top of ridge north of Clark's place, in the NW. ¼ NE. ¼ sec. 3, T. 23 S., R. 16 E.; big *Trophon* zone, about 900 or 1,000 feet stratigraphically above shale of Santa Margarita (?) formation. Lower beds.

4646. About 3 miles west of Coalinga, just north of Commercial Petroleum well No. 1, in canyon. Middle or upper beds.

4647. On top of ridge between Salt Creek and Jacalitos Creek, about 5 miles south-southeast of Alcalde, at elevation of 1,300 feet, on north line of sec. 6, T. 22 S., R. 15 E., hard sandstone layer through pebbly olive-gray sand. *Pecten estrellanus* zone about 700 to 800 feet stratigraphically below summit of formation. One of typical Jacalitos localities. Upper beds.

4649. West point of 1,308-foot ridge three-fourths mile southeast of Alcalde, SW. ¼ NE. ¼ sec. 24, T. 21 S., R. 14 E. Middle beds.

4650. Lowest fossil bed on west face of 1,900-foot hill southeast of Alcalde. Middle beds.

Numerous fragments of *Tamiosoma gregaria*, *Ostrea titan*, and *Pecten estrellanus* are scattered over the surface of the fossil-wood bearing conglomerate beds of the upper Jacalitos in the low hills south of Oilfields and 7 miles north-northeast of Coalinga, in the SE. ¼ sec. 34, T. 19 S., R. 15 E. They have the appearance of being in place in these beds, but it is believed to be more probable that they are either inclusions in the Jacalitos of fossils derived from the Santa Margarita(?) beds or recent float from the higher hills.

The species which are common to the Jacalitos and the overlying Etchegoin, but which do not extend below into the Santa Margarita(?) are *Arca trilineata* Conrad, *Cardium meekianum* Gabb, *Cryptomya ovalis?* Conrad, *Diplodonta harfordi* F. M. Anderson, *Diplodonta parilis* Conrad, *Echinarachnius gibbsii* Rémond, *Chrysodomus portolaensis* Arnold, *Macoma secta* Conrad, *Monia macroschisma* Deshayes, *Mytilus* (*Mytiloconcha*) *coalingensis* Arnold, *Ostrea atwoodi* Gabb, *Pecten oweni* Arnold, *Schizothærus pajaroanus* Conrad, *Paphia staleyi?* Gabb, and *Paphia tenerrima* Carpenter.

Thais kettlemanensis Arnold properly belongs in the list of the species unique in the Jacalitos, as it occurs alone at the type locality of the species (locality 4680, which is included in the general locality 4679), which is on the axis of the Coalinga anticline and in beds below the lowest fossiliferous horizon that is certainly Etchegoin. It is abundant toward the base of the Jacalitos.

All the determinable fossils that have been found in the Jacalitos in the southern portion of the district are of salt-water species, which indicate the marine origin of the greater part of the formation. The basin of deposition, however, appears to have been a shallow one, and it is not unlikely that portions of the great thickness of beds were deposited outside of the area occupied by the salt water at times when subsidence did not keep pace with deposition and the consequent encroachment of the land upon the sea. Beds formed at such times may be represented by the fossil-wood zones noted and possibly by some of the gravel and sand deposits in other parts of the formation.

The Jacalitos may be defined as a formation embracing about 3,600 feet of sand, gravel, clay, and sandstone, lying between the Santa Margarita (?) formation below and the Etchegoin above, and containing in its fauna among others at least 15 species which are unique, 4 which are common to it and the Santa Margarita but do not extend up into the Etchegoin, and 15 which are common to it and to the Etchegoin but do not extend down into the Santa Margarita fauna. The age of the Jacalitos is believed to be the early part of the upper Miocene. It has a known range of about 75 miles along the Diablo and Temblor ranges, from Coalinga to the Elkhorn Plain. Whether it will be possible to recognize the fauna outside of this area is not known; for the present it seems advisable

to use the name only in a local way and in the general geologic column to place it tentatively as an equivalent for the upper part of the Santa Margarita and the lower part of the San Pablo.

IMPORTANCE WITH RELATION TO PETROLEUM.

The Jacalitos formation is not petroliferous in the Eastside field in the northern part of the district, but becomes very productive in the Westside field owing to the thinning out of the formations between it and the Tejon. In the Kreyenhagen field it is not known to be productive at any point, no oil appearing to have escaped from the Tejon and Vaqueros through the shales of the Santa Margarita (?). The thickness and character of the Jacalitos throughout the district have an important bearing on the question of the accessibility of the oil, owing to the fact that most of the wells have to penetrate it in order to reach the oil sands at depths at which they will be productive. A knowledge of its thickness has been especially useful in making calculations as to the depth at which the oil sands may be found in the Kreyenhagen and Kettleman hills.

ETCHEGOIN FORMATION (UPPERMOST MIOCENE).

DEFINITION.

ORIGINAL DESCRIPTION.

The name Etchegoin series was applied by F. M. Anderson[a] to a great thickness of beds of little-consolidated sand, gravel, and clay, characteristically blue at the base, extending a long distance both northwest and southeast from Coalinga along the border of the Diablo Range. The name of the formation was "derived from its characteristic development in the vicinity of the Etchegoin ranch, some 20 miles northeast of Coalinga." This is an abandoned sheep ranch at the northern edge of the area mapped, 12½ miles northeast of Coalinga (NW. ¼ sec. 1, T 19 S., R. 15 E.). A general description of the formation was given. Its upper limit was stated to be at the base of the fresh-water deposits in the vicinity of Tulare Lake and the Kettleman Hills, described as the Tulare formation.

Mr. Anderson states that "one or two fossil horizons are to be recognized in the Etchegoin sands, one near their bottom and another some distance above." The one near the bottom is stated to be the more characteristic horizon. It is the one that will be later described as the *Glycymeris*[b] zone and as the base of the formation. The nearest locality to the Etchegoin ranch for which a description or section was given is 9 miles north of Coalinga, and this may therefore be taken as the type section. In this section the base of the forma-

[a] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: Proc. California Acad. Sci., 3d ser., vol. 2, 1905, No. 1.

[b] To avoid confusion it should be stated that this same genus was referred to as *Pectunculus* in the paper quoted. That name has been replaced by the one here used owing to the fact that *Glycymeris* was the original designation of the genus.

tion was shown considerably above the *Tamiosoma* zone, which is described in the present report as part of the Santa Margarita (?) formation. The position of the lower portion of the Etchegoin was further indicated by the statement in the general description that it was characteristically a zone of bluish sand. The whole formation was referred to the Pliocene and was stated to be unconformable with the beds below.

PRESENT DEFINITION.

In accordance with the original description, and on the basis of the reasons stated below, the Etchegoin formation is mapped and described in the present paper as the succession of beds of sand, gravel, and clay, in part indurated, occurring in the oil field northeast of Coalinga above the base of the hill-forming sandstone beds referred to for convenience as the *Glycymeris* zone, and in the Kettleman Hills below the fresh-water beds described as the base of the Tulare formation. The upper limit is not defined for the hills north of Coalinga owing to the indefiniteness of the line between the Etchegoin and Tulare there. The base of the formation may be still more sharply defined as the lowest horizon of the Tertiary beds that rest directly upon the Cretaceous in the basin of the White Creek syncline, about 15 miles northwest of Coalinga, for there no question can exist of the individuality of the Etchegoin as a stratigraphic unit or of its proper delimitations. Such a definition on the basis of the White Creek occurrence seems permissible, inasmuch as there can be little doubt that the fossiliferous beds at the base of the formation in the White Creek basin are equivalent to those north of Coalinga referred to as the *Glycymeris* zone. This fossil zone was probably at one time continuous between the two localities..

Strata in other portions of the Coalinga district are referred to the Etchegoin formation on the basis of paleontologic correlation with the basal beds on Anticline Ridge and in the White Creek basin and with the upper beds in the Kettleman Hills. The formation so described probably belongs as a whole in the Miocene, though its uppermost beds may reach into the Pliocene. It is very rich in marine fossils and is chiefly of marine origin, but evidence will be mentioned later pointing to the origin of portions of it in bodies of nearly fresh water.

BASE OF THE FORMATION.

The *Glycymeris* zone is an extremely fossiliferous bed of somewhat indurated sand that forms the summit of the hill at the northwest end of Anticline Ridge (fossil localities 4656, 4658, and 4659) and extends continuously from that point along the line mapped as the base of the Etchegoin formation. The beds of this zone are shown on the right side of Plate XVIII, along the summit of Anticline Ridge, in the middle distance in the picture. The zone is underlain at this locality by clay that forms a belt of low relief in the topography and that is

classed in the Jacalitos formation. It is overlain by a thick succession of bluish-gray sand beds interbedded with dark-gray sand. The zone affords almost perfect specimens of many species of fossils that make up a distinctive fauna. It is called the *Glycymeris* zone for ease of reference, because it is an important datum line that may be recognized by the association of fossils contained in it. It could not be identified surely by the *Glycymeris* alone, for although the genus is perhaps more characteristic of this zone than of any other, its distribution at other horizons is wide. Approximately, if not exactly, the same horizon marks the base of the beds overlying the Cretaceous sandstone in the synclinal basin of White Creek, as shown by the typical association of fossils (fossil localities 4662, 4663, and 4664). Somewhere between Oil Canyon and the White Creek area an overlap of the Etchegoin upon the Jacalitos and earlier Tertiary formations must have taken place.

It is therefore appropriate to consider the beds above the base of the *Glycymeris* zone as a distinct formation, although on Anticline Ridge and in the greater portion of their extent in the region north of Coalinga, as well as to the south as far as they have been studied, they appear to rest conformably upon the beds below. The fact that the *Glycymeris* zone or fossil beds that are approximately equivalent to it are traceable throughout the district gives it great value in distinguishing the Etchegoin from the formation below.

TOP OF THE FORMATION.

In the section of this formation in the hills north and northwest of Coalinga the summit has not been found clearly marked, but it is overlain around the edge of the valley by gravel, sand, and clay deposits that are with little doubt the equivalent of part of the formation which has at its base a clearly marked bed of fresh-water fossils at the northern end of the Kettleman Hills, less than 10 miles to the south. That formation, the Tulare, is widespread along the border of the Diablo Range in contact with the Etchegoin. The occurrence of the Etchegoin, especially of the upper portion, is typical in the Kettleman Hills, and the contact is distinctly traceable between its uppermost beds, which are full of marine or estuarine fossils, and the fresh-water bed immediately overlying. There is reason to believe that if the beds of these formations were well exposed near their contact in the hills northeast of Coalinga the same fossil zone would be found and the summit of the Etchegoin would be well defined, as it is in the Kettleman Hills. An appearance of conformity and intergradation between the Etchegoin and Tulare exists along the contact in the Kettleman Hills, although a time break may have intervened without leaving any marked evidence as yet observed. In the Kreyenhagen Hills there may be an unconformity, and that will be discussed later.

[redacted]

[redacted]

elements of the river, and moreover, the [redacted]
formation are in large part composed of sand and sandstone [redacted]
they have been found exposed

F. M. Anderson divided his Etchegoin series into the Etchegoin sands below and the San Joaquin clays above, corresponding to the rough divisions already outlined; but inasmuch as these names are not applicable throughout the area under discussion and do not represent a complete division of the formation they are not used in the present paper.

DISTRIBUTION AND LOCAL CHARACTER.

ETCHEGOIN IN THE COALINGA FIELD.

In the oil field north of Coalinga the Etchegoin has a maximum thickness of about 1,700 feet. The *Glycymeris* zone already described is at the base and a number of other fossiliferous beds lie within several hundred feet above this, affording altogether a rich fauna. (See fossil localities 4657, 4671, and 4688.) The lower portion of the formation is composed largely of beds of compact coarse and fine bluish-gray sand alternating with zones of pebbly sand, fine gray sand, and some clay, with occasional more hardened beds. The clay increases toward the upper part of the formation, being interbedded with unconsolidated light-gray sand that spreads over the surface and obscures the structure. The formation occurs in the low hills bordering the valley and passes beneath the alluvium of the floor.

The Etchegoin forms a belt along the edge of the Alcalde Hills west of Coalinga and is overlapped by the recent valley deposits. The formation is described in connection with the section (fig. 4), which represents its exposures on the summit and east slope of the 1,410-foot hill 2 miles southwest of Coalinga. The beds there are chiefly of yellowish and gray gypsiferous sand, sandstone, and gravel of various degrees of coarseness, and have an exposed thickness of about 750 feet. A fossil bed about equivalent to the *Glycymeris* zone at the base of the formation farther northeast outcrops near the top of the hill, and a 20-foot fossil bed equivalent to the *Pecten coalingaensis* zone of the Kreyenhagen and Kettleman hills appears at the edge of the valley about 650 feet above the base of the formation as mapped (fossil locality 4714). As the uppermost beds that belong above the *Pecten coalingaensis* zone are hidden by the surface deposits of the valley, the whole formation here may have a thickness of 900 or 1,000 feet. Probably the formation is overlain beneath the valley by the Tulare.

ETCHEGOIN IN THE WHITE CREEK BASIN.

A detached area of Etchegoin beds is preserved in the syncline near the head of White Creek, as before mentioned. At one time these beds were doubtless continuous with those of the same formation around Pleasant Valley. The lowest 100 feet of beds, immediately overlying the Cretaceous, are composed of coarse and pebbly, compact

GENERAL DESCRIPTION.

In the description of the Jacalitos (early upper Miocene) frequent reference has been made to the overlying Etchegoin (uppermost Miocene). In fact, these formations are so closely related and so similar that the one can not well be described without reference to the other. In the southern part of the district they seem to have originated as a chronologically continuous succession of deposits and are only arbitrarily separable on the basis of the associations of faunas, whereas in the northern part of the district they are not so completely represented, and movement of the land took place that caused the later deposits to spread more widely than those of the earlier period. Many of the features of structure, influence upon topography, and lithologic variation mentioned in connection with the Jacalitos are common to both.

The surface exposure of the upturned beds of the Etchegoin formation, as shown by the map, forms a belt along the foothills similar to that of the Jacalitos, the beds lying above those of the Jacalitos in the general monoclinal succession. Along the main belt where the beds of the Etchegoin lie they dip at all angles, varying from a few degrees to the vertical, but generally with regularity at each locality. The formation attains its greatest thickness in the southern part of the district, in the Kreyenhagen Hills, where it is at least 3,500 feet thick. In the northern portion it is at most only half as thick.

The formation is made noticeable by the dominant grayish-blue color of the massive sand beds that are dispersed through several hundred feet of beds at its base, but an examination of its characteristic fossils, which abound at several different horizons, is the only means of distinguishing it accurately from the associated formations. The blue color of the sands has been mentioned above (p. 115). An exposure of soft sandstone and gravel beds in the middle of the formation is shown in Plate IX, *B*. The outcrops and general topography at the point where this picture was taken are characteristic, although the sand dollars are somewhat more numerous than in most places.

One of the most important of the broad features of the formation in the Coalinga district is the usual predominance of coarse material, such as sand and pebbly deposits, in its lower portion, and of finer material, such as extremely fine sand and clay, in its upper portion, but this feature is characteristic in various degrees according to the locality, and in some places is hardly noticeable. It can not be said of any locality that either portion is free from an admixture of the elements of the other, and, moreover, the uppermost beds of the formation are in large part composed of sand and sandstone wherever they have been found exposed.

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but soft yellowish-gray sandstone hardly distinguishable from the underlying Cretaceous sandstone. These beds do not contain very many fossils, but grade upward into beds largely composed of fossils, with a matrix of yellowish-gray sand. This basal fossil zone contains a fauna closely resembling that of the *Glycymeris* zone on Anticline Ridge and is correlated with it. (See fossil localities 4662, 4663, and 4664.) The bulk of the formation in its middle portion consists of similar sand and sandstone resembling the massive upper Cretaceous sandstone and containing occasional fossil beds. Numerous layers of very hard sandstone and some concretions are present. The beds for a few hundred feet below the top of the formation are more variable, a thick zone of coarse pebbles being followed above by alternating beds of sandy shale, calcareous shale, and coarse and fine sand and sandstone, with a hard and prominent thin bed of dark-brownish sandstone full of small white fossils near the top. The total thickness of the beds here preserved is about 1,100 feet.

The basal beds of the Etchegoin are apparently conformable in dip with the Cretaceous in the White Creek syncline, although of course the break between the two periods was profound. The beds at the base dip at angles as high as 60° or more along parts of the syncline, but the dip decreases gradually to only a few degrees in the axis of the fold. The character of the sand forming the Etchegoin beds indicates that it was derived largely from the Upper Cretaceous sandstone beds.

ETCHEGOIN IN WALTHAM VALLEY.

The continuation of this basin deposit of Etchegoin forms a filling in the region of open hills toward the head of Los Gatos Creek, where it overlies both Cretaceous and Franciscan, and in the synclinal trough of Waltham Valley, which extends for many miles along the western side of Juniper Ridge outside of the area mapped.

ETCHEGOIN IN THE KREYENHAGEN HILLS.

The best and most complete sections of the Etchegoin may be found in the Kreyenhagen Hills, where the upturned northeastward-dipping beds of this formation are exposed as a belt between the Jacalitos and Tulare formations. It is not easily separable from these two formations. The contact at the base of the Etchegoin is drawn below a fairly constant fossiliferous zone, which is supposed to be the equivalent of the *Glycymeris* zone north of Coalinga. The contact at the top of the formation is marked by the usual occurrence above it of the gravelly beds of the Tulare, by a summit zone containing Myas, oysters, etc., that may be called the upper *Mya* zone, and by other more local criteria.

The zone of blue-sand beds at the base of the formation is constant throughout the Kreyenhagen Hills. Its thickness varies from place

to place and its position is of little value except for rough correlations. The thickness of the blue-sand zone within the Etchegoin near Zapato Creek is over 2,500 feet, whereas at points south of Big Tar Canyon the beds characterized by this blue color have not been observed to extend as much as 800 feet above the base of the formation. The lower part of the formation is composed chiefly of sandy beds of all degrees of coarseness up to pebble beds, and of many varieties of blue, gray, and drab color, with minor amounts of clay. The upper part of the formation is composed of alternating thick zones of sand and clay, the clay being somewhat more in evidence than in the lower portion.

There are four main fossil zones in the Etchegoin of the Kreyenhagen Hills, corresponding to similar ones found in some other parts of the district. The lowest one is at the base of the formation and is the approximate equivalent of the *Glycymeris* zone farther north and of the lower *Mulinia* zone of the Kettleman Hills. About 800 feet above the base of the formation, roughly speaking, comes a zone that may be referred to here and in the Kettleman Hills as the upper *Mulinia* zone, as it is the uppermost bed in which large specimens of this genus are found. This zone is usually approximately coincident with the upper portion of the blue-sand zone. The third main zone may be called the *Pecten coalingaensis* zone owing to the nonoccurrence of this species at other horizons. It is within 300 to 400 feet below the top of the formation and contains a well-preserved and extremely varied fauna, including *Pecten coalingaensis* and *Pecten wattsi* as about the most typical forms, together with many sand dollars, sea urchins, brachiopods, etc. The fourth zone includes the summit beds of the formation, which contain Myas, oysters, etc., and which are called the upper *Mya* zone. These four zones do not include all the important fossil beds in the formation, but are those that have been found most persistent and easily recognizable and therefore most valuable as datum zones.

The following sections of the formation in different parts of the Kreyenhagen Hills, together with the section in figure 4, give a tabulated description of the formation as it occurs typically and convey an idea of the variety of the beds.

Section of Etchegoin formation on Canoas Creek.

	Feet.
Fine gray sand and clay, with occasional hard layers, upper *Mya* zone (fossil localities 4744 and 4782); overlain by gravel of Tulare	450
Gray sand and clay in alternating beds of variable thickness	1,700
Top of blue sandstone; massive gray sand, both coarse and fine, interbedded with clay in lesser amounts and occasional heavy beds of blue sand; contains numerous sand dollars (locality 4707) and a zone at the base with many fossils; the upper *Mulinia* zone	550
Similar beds to the base of the zone of blue sand. Beds at base containing many fossils (locality 4769), probable equivalent of the *Glycymeris* zone and of lower *Mulinia* zone of Kettleman Hills	900
	3,600

Section of Etchegoin formation 3½ miles southeast of Big Tar Canyon.

	Feet.
Thinly bedded hard white porcelaneous shale, with whitish-gray fine sand, pebbly sand, and sandy clay, containing lenticular layers and nodules of porcelaneous shale and many bone fragments; summit of Etchegoin not definitely determinable, but this zone so mapped	250
Alternating thick zones of whitish-gray sand and clay	1,080
Solid zone of thin-bedded pebbly sandstone	45
Whitish-gray sand and clay with a 15-foot bed of coarse pebbly sand in middle	660
Prominent beds of compact gray sand with softer sand and sandy clay between; whitish-gray sand with black pebbles at base	210
Compact fine gray sand streaked with layers of fine whitish sand and sandy clay	420
Compact, slightly gritty white shale somewhat similar to Santa Margarita (?)	10
Solid zone of gray sandstone, coarse pebbly sandstone, and hard calcareous shale	40
Fine gray sand	50
Highest bed of blue sand, with a 10-foot layer of pebbles at base and a 3-foot layer full of sand dollars, barnacles, Arcas, etc., 20 feet above base; probably upper *Mulinia* zone	80
Interbedded blue sand and sandy clay with a prominent 20-foot bed of blue sand at base	120
Minor beds of blue sand, with a thick zone of hard calcareous shale in middle	90
Prominent blue-sand bed, pebbly toward the base and containing many sand dollars	90
Soft gray sand	70
Very prominent blue sand	40
A prominent 30-foot bed of blue sand at base overlain by bluish and gray sand and three less prominent beds of blue sand	250
	3,500

ETCHEGOIN IN M'LURE VALLEY.

The Etchegoin probably outcrops over a small area in the Avenal syncline in McLure Valley above the Jacalitos formation, but it can not be definitely recognized. The thickness of beds above the Santa Margarita(?) formation is so great in this region that some Etchegoin must be present in addition to the Jacalitos. No fossils have been found and there is no direct evidence on which to base a separation between the two formations, so that the line of contact mapped is arbitrary. The highest beds appearing in the syncline, which are taken to be the basal beds of the Etchegoin, consist of blue sands. Above these everything is covered by the recent alluvial deposits of the valley.

ETCHEGOIN IN THE KETTLEMAN HILLS.

The Etchegoin is excellently exposed in the Kettleman Hills, where it is a thick formation similar in general character to the same terrane in other parts of the district. Its lower portion appears along the axis of the Coalinga anticline, but although the lowest beds that the plunging anticline brings to the surface are very nearly the basal beds of the formation no underlying formation is known to be exposed. The uppermost beds appear all around the Kettleman Hills and are everywhere overlain, with apparent conformity, by the fresh-water

beds at the base of the Tulare. The greatest thickness that has been found exposed is in the south-central part of the hills, on the southwest flank of the anticline, where the beds below the fresh-water horizon measure over 3,000 feet.

Different horizons in the Etchegoin of the Kettleman Hills afford good datum lines that may be recognized by means of the characteristic faunas and the constancy of the beds containing them, and it is convenient to designate these briefly, beginning with the summit of the formation as a constant datum line and going down. In addition to the main zones that will be here mentioned there occur other fossil beds which may assume local importance, but which were not found so constant. Complete lists of the fossils contained in these zones at different localities are given below. In this connection reference should be made to the section in figure 5 and the tabulated section on page 123. The summit of the formation is marked, as it is in portions of the Kreyenhagen Hills, by a constant fossiliferous zone of sand and sandstone interbedded with dark clay, which may be called here, like the same zone in the Kreyenhagen Hills, the upper *Mya* zone, because of the great abundance of Myas. It also contains many other fossils, especially common being small yellow Littorinas and small oysters. This zone has a thickness varying between 200 and 300 feet and is prominent in the topography because it usually forms a line of hills. In the southern part of the Kettleman Hills it forms the main ridge. This zone and the transition between it and the overlying fresh-water beds is further discussed in connection with the Tulare formation. Below it comes a zone of unequal thickness, but usually about 700 feet thick, which in some portions of the hills is composed almost entirely of fine inky-blue clay, and in others of clay and sand interbedded in varying proportions. Toward the base of this zone, usually between 700 and 900 feet below the top of the formation, there is a zone of fossiliferous sandstone beds that is the equivalent of the zone of *Pecten coalingaensis* in the Kreyenhagen Hills. These beds likewise show a tendency to form hills or knobs, but they are not as prominent as those of the upper *Mya* zone. Below the *Pecten coalingaensis* zone the formation is largely sand and clay, chiefly sand, down to the base, the lower portion being composed as elsewhere of alternating beds of ordinary sand and blue sand. The next prominent fossil bed to be mentioned is another one containing a great many Myas, and it will be referred to as the lower *Mya* bed. It occurs between very prominent beds of blue sand on the summits of hills, and in the north-central portion of the Kettleman Hills forms the main ridge. Owing to the fact that the formation is thicker in the southern than in the northern portion of the hills and apparently thicker on the western than on the eastern flank of the anticline, the distance below

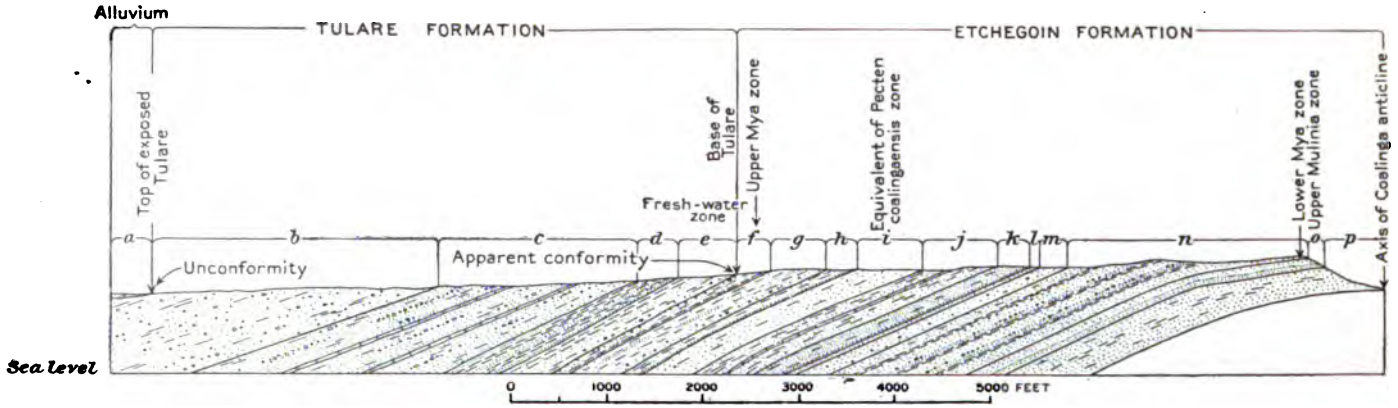

FIGURE 5.—Section of Tulare and Etchegoin formations along road 6 miles from northwest end of Kettleman Hills on southwest flank of Coalinga anticline, along line N–N′ on geologic map (Pl. I).

	Feet.
a. Alluvium.	
Tulare.	
b. No good outcrops but probably alternating sand, coarse gravel, and clay; highest Tulare exposed	700+
c. Chiefly light-gray sand affording a light sandy soil, interbedded with straw-colored earthy clay, and with occasional beds of gravel and thin layers of hard sandstone	700
d. Gypsiferous dark clay, with thin beds of sand	160
e. Incoherent gray sand and clay, with fresh-water fossils in lower portion; base of Tulare	260
	1,820+
Etchegoin.	
f. Yellowish-gray sand and clay, with some dark clay; many fragments of porcelain shale on surface, small oysters in sand at top, and yellow calcareous shale lenses in bluish-black clay at base; upper *Mya* zone, top of Etchegoin	125
g. Alternating beds of gypsiferous fine drab sand, sandy clay, and drab to bluish clay, with occasional sandstone layers, and with bed at base containing delicate fossils, *Nucula*, etc	250
h. Similar beds, with layers of iron-stained sandstone at base	115
i. Similar gypsiferous beds, with light-colored sand predominating; the *Pecten coalingaensis* zone should be here somewhere but was not found	250
j. Inky-blue clay with minor beds of sand and with a hard 1-foot bed of yellow limestone in middle	290
k. Fine sand and some light and dark clay, with hard, very gypsiferous yellow and variegated sandstone at the top and interspersed hard layers below; sandstone with *Solen*, etc., near base	135
l. Highest blue-sand bed	45
m. Grayish-blue massive sand and pebbly sand, with fossils	130
n. Thinly and massively bedded drab and light-gray sand, with occasional beds of blue sand and layers of inky-blue clay, white clay, and pebbles; the sand at base is the lower *Mya* bed (fossil locality 4676)	550
o. Massive beds of blue and gray sand, with *Mulinia*, etc., at base; upper *Mulinia* zone	150
p. Less prominent beds of blue and gray sand and dark clay, with *Echinarachnius*, *Ostrea*, *Cardium*, etc., toward base (fossil locality 4678)	350
	2,390
Total Tulare and Etchegoin	4,310+

The base of the Etchegoin is probably several hundred feet lower.

the summit of the formation at which this and other beds can not be stated as a constant. The variation of this zone is between about 1,900 and 2,400 feet below the summit. One of the fossils most in evidence in the Kettleman Hills is the large *Mulinia*, and a bed containing abundant specimens of this form lies about 100 feet below the lower *Mya* bed. It marks the highest horizon at which the large specimens have been found and is, as far as can be told, the equivalent of the upper *Mulinia* zone in the Kreyenhagen Hills. In the northern portion of the Kettleman Hills it is near the base of the exposed series and is the lowermost easily recognizable zone, whereas in the central portion of the hills beds of considerable thickness are exposed below. Inasmuch as the base of the Etchegoin can not be mapped in these hills the upper *Mulinia* bed is taken as a datum line in the lower portion of the formation and its summit is mapped. It can not be definitely traced at all points along the line mapped, but its horizon has been approximated as nearly as possible where its fossils and those of the overlying lower *Mya* bed have not been found. Another zone in the Kettleman Hills in which *Mulinia* is very abundant is between 500 and 700 feet below the upper one, and may be referred to as the lower *Mulinia* zone. It is approximately the equivalent of the *Glycymeris* zone in the Coalinga field. It is about the lowest bed exposed and is approximately the base of the Etchegoin formation.

The following tabulated section and the section in figure 5 represent the lithologic character and variations of the Etchegoin in the Kettleman Hills. Variation is the rule and it would be difficult to find any two sections in which the same beds are exposed and the characteristics are constant. On the northeast flank of the anticline the beds are repeated with approximately the same thickness, but the sections measured made it appear that there was possibly a slight thinning on that side.

The following section is on the southwest flank of the anticline in the south-central portion of the hills, beginning at the 1,030-foot hill on the main ridge 5 miles northwest of the Dudley-Lemoore road (in the center of sec. 3, T. 23 S., R. 18 E.), and extending northeastward across the strike of the beds to the anticlinal axis.

Section of Etchegoin formation on southwest flank of Coalinga anticline in central portion of Kettleman Hills.

	Feet.
Inky-blue clay below fresh-water bed	50
Yellow and gray sand full of fossils and of fragments or nodules of porcelain shale; the upper *Mya* zone (fossil locality 4730)	200
Inky-blue clay zone; sandy beds at top containing innumerable small oysters; occasional layers of yellow calcareous shale; a thin bed, 15 feet above base, of coarse purple and yellow, iron-stained, and exceedingly gypsiferous sandstone with many fossils (locality 4693), probably the *Pecten coalingaensis* zone.	725

	Feet.
[illegible]y light-gray and drab sand, with beds of dark clay in minor amount; a pebbly sand layer 200 feet below top; pebbly sand and iron-hardened sandstone layers near base	1,400
Blue-sand zone, several massive beds of blue sand and pebbly sand interbedded with fine light-gray and drab sand, sandy shale, and pebbly sand and occasional iron-hardened beds; at top is probably the upper *Mulinia* zone; the basal sand is full of fossils and is the lower *Mulinia* zone (locality 4689)	675
	3,050

The upper *Mulinia* zone occurs 2,000 feet below the summit of the Etchegoin in the section in figure 5, whereas the bed that has been correlated with it in the above tabulated section occurs over 300 feet lower. It seems probable from this and similar instances in the case of other sections that there is a thickening of the formation toward the south between the top and this bed, similar to the thickening that takes place between the oil field north of Coalinga and the Kreyenhagen Hills. It may reasonably be assumed that a thickening takes place below the upper *Mulinia* zone as well, and that the base of the formation is not as far below this zone in the northern portion of the hills as farther south.

Toward the north end of the hills, as shown by the map, the Etchegoin plunges completely beneath the Tulare formation and does not appear again until brought up by the oppositely plunging anticline on Anticline Ridge. Toward the southern end of the hills the formation becomes covered more and more by surface sand and soil, and its zones and structure are obscured. At the south end of the hills it does not pass below the Tulare, but exposes its lower beds.

FOSSILS, ORIGIN, AND AGE.

FOSSILS.

Fossils are found more or less abundantly and usually in an excellent state of preservation throughout the Etchegoin formation in the Coalinga district. Several recognizable zones, each carrying a more or less distinctive fauna, occur between the base and top of the formation, but these faunas are closely related and have not been deemed worthy of recognition in the mapping. The following species have been found by the writers in and near the district under discussion:

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district.

Name.	3849.	4643.	4648.	4656.	4657.	4658.	4659.	4660.	4661.	4662.	4663.	4664.	4665.	4669.	4670.	4671.	4672.	4673.	4674.	4675.	4676.	4677.	4678.	4679.	4681.	4682.	4683.	4684.	4688.	4690.
ANTHOZOA.																														
Astrangia coalingensis Vaughan																														
ECHINODERMATA.																														
Astrodapsis cf. tumidus Rémond																														
Astrodapsis sp. *a*																														
Echinarachnius gibbsii Rémond	×	×			×				×	×						×		×	×					×				×	×
Scutella perrini Weaver																														
BRACHIOPODA.																														
Terebratalia occidentalis Dall																														
Terebratalia smithi Arnold																														
PELECYPODA.																														
Arca trilineata Conrad			×	×				×		×		×	×		×			×		×			×	×						
Arca sp. *a*																														
Cardium coosense Dall								×												×										
Cardium meekianum Gabb								×					×								×		×	×						
Cardium sp. indet																														
Chama pellucida Broderip																														
Clidiophora punctata Conrad																														
Cryptomya ovalis Conrad																														
Cryptomya quadrata Arnold													×																	
Cumingia californica Conrad				×																										
Diplodonta harfordi F. M. Anderson																														
Diplodonta parilis Conrad																														
Glycymeris coalingensis Arnold				×					×			×					×													
Glycymeris septentrionalis Middendorf					×		×	×		×								×										×		
Glycymeris sp. indet																			×											
Macoma inquinata Deshayes				×												×		×					×	×						
Macoma nasuta Conrad				×									×																	
Macoma secta Conrad																														
Macoma sp. *a*																														
Mactra albaria Conrad													×																	
Mactra coalingensis Arnold													×																	
Metis sp. indet															×															
Modiolus directus Dall																														
Modiolus rectus Conrad				×																										
Mulinia densata Conrad		×		×	×		×																×	×	×	×	×	×		
Mya japonica Jay													×								×	×	×							
Mytilus (Mytiloconcha) coalingensis Arnold				×		×		×				×				×	×							×					×	

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	3849.	4643.	4648.	4650.	4657.	4658.	4659.	4660.	4661.	4662.	4663.	4664.	4665.	4669.	4670.	4671.	4672.	4673.	4674.	4675.	4676.	4677.	4678.	4679.	4681.	4682.	4683.	4684.	4688.	4690.
PELECYPODA—continued.																														
Nucula castrensis Hinds																														
Ostrea atwoodi Gabb		×	×									×											×	×						
Ostrea lurida Carpenter																														
Ostrea vespertina Conrad																														
Ostrea vespertina Conrad var. sequens Arnold																														
Ostrea sp.												×																		
Panopea generosa Gould						×								×																
Paphia staleyi? Gabb		×		×	×	×						×												×						
Paphia tenerrima Carpenter				×				×		×		×	×																	
Paphia truncata? Gabb				×																										
Pecten coalingaensis Arnold																														
Pecten deserti Conrad																														
Pecten nutteri Arnold																														
Pecten oweni Arnold				×			×	×		×	×	×		×																
Pecten wattsi Arnold												×																		
Pecten wattsi Arnold var. etchegoini F. M. Anderson																														
Phacoides acutilineatus Conrad												×																		
Pholadidea ovoidea Gould																														
Placunanomia californica Arnold																														
Saxidomus nuttalli Conrad				×		×										×														
Schizothærus nuttalli Conrad					×	×																		×						
Schizothærus pajaroanus Conrad													×																	
Semele rubropicta Dall																														
Siliqua cf. nuttalli Conrad																								×						
Siliqua sp. indet																														
Solen sicarius Gould		×											×					×			×								
Solen sp. indet																														
Transennella californica Arnold																														
Zirphæa gabbi Tryon																														
GASTEROPODA.																														
Astyris richthofeni Gabb																														
Bathytoma carpenteriana Gabb var. fernandoana Arnold																														
Calliostoma coalingensis Arnold																														
Calliostoma kerri Arnold																														
Cancellaria tritonidea Gabb																			×											
Chrysodomus imperialis Dall																														
Chrysodomus portolaensis Arnold													×	×																
Crepidula princeps Conrad													×	×																

| | | |

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4693.	4695.	4696.	4697.	4698.	4699.	4700.	4701.	4702.	4703.	4704.	4705.	4706.	4707.	4708.	4709.	4710.	4711.	4712.	4713.	4714.	4715.	4716.	4717.	4718.	4720.	4722.	4723.	4724.	4725.
ANTHOZOA.																														
Astrangia coalingensis Vaughan																	×													
ECHINODERMATA.																														
Astrodapsis cf. tumidus Rémond																×	×		×											
Astrodapsis sp. *a*																														
Echinarachnius gibbsii Rémond	×						×						×	×	×		×		×	×	×	×								
Scutella perrini Weaver																			×	×										
BRACHIOPODA.																														
Terebratalia occidentalis Dall																														
Terebratalia smithi Arnold																			×		×									
PELECYPODA.																														
Arca trilineata Conrad	×	×						×							×	×	×		×		×			×	×					×
Arca sp. *a*																														
Cardium coosense Dall																×														
Cardium meekianum Gabb																														
Cardium sp. indet																														
Chama pellucida Broderip																×	×													
Clidiophora punctata Conrad																														
Cryptomya ovalis Conrad	×																													
Cryptomya quadrata Arnold																														
Cumingia californica Conrad																														
Diplodonta harfordi F. M. Anderson																														
Diplodonta parilis Conrad																														
Glycymeris coalingensis Arnold																														
Glycymeris septentrionalis Middendorf																														
Glycymeris sp. indet																														
Macoma inquinata Deshayes																						×			×	×	×	×		×
Macoma nasuta Conrad												×					×					×								
Macoma secta Conrad																														
Macoma sp. *a*																														
Mactra albaria Conrad																														
Mactra coalingensis Arnold																														
Metis sp. indet																														
Modiolus directus Dall																														
Modiolus rectus Conrad					×																									
Mulinia densata Conrad		×		×	×																									
Mya japonica Jay		×																				×			×	×	×	×		×
Mytilus (Mytiloconcha) coalingensis Arnold	×																				×									

| | | |

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4693.	4695.	4696.	4697.	4698.	4699.	4700.	4701.	4702.	4703.	4704.	4705.	4706.	4707.	4708.	4709.	4710.	4711.	4712.	4713.	4714.	4715.	4716.	4717.	4718.	4720.	4722.	4723.	4724.	4725.
GASTEROPODA—continued.																														
Neverita recluziana Petit	×			×				×	×	×	×	×				×	×		×											
Neverita recluziana Petit var. alta Dall																×														
Olivella biplicata Conrad																														
Olivella pedroana Conrad																	×													
Opalia sp. indet																			×											
Pisania fortis Carpenter var. angulata Arnold																														
Pleurotoma coalingensis Arnold																														
Sigaretus scopulosus Conrad																														
Thais crispatus Chemnitz				×											×															
Thais crispatus Chemnitz, nearly smooth var																														
Thais etchegoinensis Arnold		×		×															×											
Thais kettlemanensis Arnold																														
Trochita filosa Gabb	×														×										×		×			
Trophon (Forreria) coalingense Arnold																														
Trophon (Forreria) ponderosum Gabb																														
Trophon (Boreotrophon) stuarti Smith																			×											
Turritella vanvlecki Arnold																														
Xylotrya sp																						×								
CIRRIPEDIA.																														
Balanus sp																														
Balanus large sp																														
Balanus concavus Bronn																	×		×											
Taniosoma gregaria? Conrad																														
CRUSTACEA.																														
Cancer fissus Rathbun																														
Loxorhynchus grandis Stimpson																														
PISCES.																														
Fish bones of various kinds						×										×												×	×	
Carcharodon arnoldi Jordan																×				×										
Fish, bulbous growths		×	×	×		×																×								
Fish spines			×																											
Fish vertebræ																														
CETACEA.																														
Cetaceæ (vertebræ)				×																										

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4728.	4729.	4730.	4736.	4741.	4744.	4749.	4750.	4751.	4752.	4753.	4754.	4755.	4756.	4757.	4758.	4759.	4760.	4761.	4762.	4763.	4769.	4778.	4780.	4781.	4782.	4783.	4799.	4806.	4857.
ANTHOZOA.																														
Astrangia coalingensis Vaughan																×														
ECHINODERMATA.																														
Astrodapsis cf. tumidus Rémond																	×													
Astrodapsis sp. *a*																														
Echinarachnius gibbsii Rémond							×	×	×		×		×	×	×	×	×		×									×	×	
Scutella perrini Weaver																														
BRACHIOPODA.																														
Terebratalia occidentalis Dall			×																											
Terebratalia smithi Arnold																×														
PELECYPODA.																														
Arca trilineata Conrad				×			×	×							×	×	×	×		×	×	×		×	×			×	×	×
Arca sp. *a*																												×		
Cardium coosense Dall																					×									
Cardium meekianum Gabb								×							×				×										×	
Cardium sp. indet																						×								
Chama pellucida Broderip																														
Clidiophora punctata Conrad																													×	
Cryptomya ovalis Conrad			×													×														
Cryptomya quadrata Arnold																														
Cumingia californica Conrad																×														
Diplodonta harfordi F. M. Anderson																													×	
Diplodonta parilis Conrad														×		×					×								×	
Glycymeris coalingensis Arnold								×						×		×					×								×	
Glycymeris septentrionalis Middendorf																													×	
Glycymeris sp. indet																														
Macoma inquinata Deshayes				×		×	×	×		×				×		×										×				
Macoma nasuta Conrad														×		×														
Macoma secta Conrad																													×	
Macoma sp. *a*														×						×										
Mactra albaria Conrad																														
Mactra coalingensis Arnold																				×									×	
Metis sp. indet																						×								
Modiolus directus Dall																		×												
Modiolus rectus Conrad						×										×								×						
Mulinia densata Conrad						×	×	×				×		×		×						×						×		
Mya japonica Jay		×		×		×				×		×				×										×				
Mytilus (Mytiloconcha) coalingensis Arnold				?			×	×								×													×	

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4728.	4729.	4730.	4736.	4741.	4744.	4749.	4750.	4751.	4752.	4753.	4754.	4755.	4756.	4757.	4758.	4759.	4760.	4761.	4762.	4763.	4769.	4778.	4780.	4781.	4782.	4783.	4799.	4906.	4857.
PELECYPODA—continued.																														
Nucula castrensis Hinds	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ostrea atwoodi Gabb	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....
Ostrea lurida Carpenter	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....
Ostrea vespertina Conrad	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	....	....	....	....	....
Ostrea vespertina Conrad var. sequens Arnold	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ostrea sp.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Panopea generosa Gould	....	....	....	....	....	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Paphia staleyi Gabb	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....
Paphia tenerrima Carpenter	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Paphia truncata? Gabb	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pecten coalingaensis Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pecten deserti Conrad	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	~	....	....	....	....
Pecten nutteri Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pecten oweni Arnold	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	×	×
Pecten wattsi Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	....	....	....	....	....
Pecten wattsi Arnold var. etchegoini F. M. Anderson	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Phacoides acutilineatus Conrad	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pholadidea ovoidea Gould	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Placunanomia californica Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Saxidomus nuttalli Conrad	....	....	....	....	....	....	×	×	....	....	....	....	....	×	×	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....
Schizothærus nuttalli Conrad	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Schizothærus pajaroanus Conrad	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Semele rubropicta Dall	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Siliqua cf. nuttalli Conrad	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Siliqua sp. indet	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Solen sicarius Gould	....	....	....	×	....	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....
Solen sp. indet	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Transennella californica Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Zirphæa gabbi Tryon	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
GASTEROPODA.																														
Astyris richthofeni Gabb	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	×	....
Bathytoma carpenteriana Gabb var. fernandoana Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Calliostoma coalingensis Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Calliostoma kerri Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cancellaria tritonidea Gabb	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chrysodomus imperialis Dall	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chrysodomus portolaensis Arnold	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×
Crepidula princeps Conrad	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	×

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3849. Point where road from Coalinga to Stone Canyon crosses the Waltham Creek sheep property. Spur of sandstone. Middle beds.

4643. Upper *Mulinia* zone on main ridge of Kettleman Hills 1 mile southeast of 1,370-foot hill, in the SE. ¼ sec. 20, T. 22 S., R. 18 E. Lower middle beds.

4648. Seventy-five feet below summit on south side of 1,375-foot hill just west of Mr. Orr's house in Big Tar Canyon, in the NE. ¼ NW. ¼ sec. 8, T. 23 S., R. 17 E. Basal beds.

4656. At northwest end of Anticline Ridge, 6 miles north-northeast of Coalinga, SW. ¼ sec. 34, T. 19 S., R. 15 E. Lowest Etchegoin bed or *Glycymeris* zone, just below bed of 4657.

4657. At northwest end of Anticline Ridge, 6 miles north-northeast of Coalinga; bed just above 4656; near south side of SW. ¼ sec. 34, T. 19 S., R. 15 E. Basal beds.

4658. Near northwest end of Anticline Ridge, at southeast end of long 1,200-foot hill, in NE. ¼ sec. 3, T. 20 S., R. 15 E. Near base of Etchegoin.

4659. At northwest end of Anticline Ridge on 1,200-foot hill and for 1 mile northwest of that hill along *Glycymeris* zone. Basal beds. See 4656.

4660. About 2½ miles southwest of Coalinga, northeast of West Coalinga well. *Glycymeris* zone or basal beds. See locality 4674.

4661. Eight miles north of Coalinga, in the NW. ¼ sec. 29, T. 19 S., R. 15 E. *Glycymeris* zone or basal beds.

4662. At north edge of Etchegoin area in White Creek basin, one-half mile east of road up White Creek and three-fourths mile southeast of Michigan well, center of NW. ¼ sec. 16, T. 19 S., R. 13 E. *Glycymeris* zone, 100 feet above base of Etchegoin.

4663. At north edge of Etchegoin area in White Creek basin, on summit of ridge one-half mile west of road up White Creek and three-fourths mile southwest of Michigan well, about 1 mile northwest of 4662. In basal sandstone of the Etchegoin.

4664. On north side of White Creek about 5 miles northwest of junction with Los Gatos Creek. In basal Etchegoin beds on south side of synclinal basin.

4665. On south side of White Creek about 6 miles northwest of junction with Los Gatos Creek. Basal beds.

4669. At south end of Kettleman Hills, on summit of 540-foot hill in the very southwest corner of area mapped, in center of sec. 2, T. 25 S., R. 19 E., and for 1 mile S. 15° E. of that hill. Probably about the lowest Etchegoin beds exposed south of Avenal Gap.

4670. At southernmost end of Kettleman Hills, 5¼ miles south-southeast of Light's house in Avenal Gap, on knob of vertical angle B. M. (elevation 505 feet), in center of sec. 10, T. 25 S., R. 19 E. Prominent bed of yellowish limestone in uppermost portion of Etchegoin.

4671. On northeast flank of Anticline Ridge, about 6½ miles northeast of Coalinga and about 2 miles north-northeast of B. M. 947 feet. Several hundred feet above base of Etchegoin, in the lower middle beds.

4672. South of Waltham Creek, 3½ miles southwest of Coalinga, on northeast nose of 1,200-foot ridge four-fifths mile north-northwest of 1,900-foot hill, center of SE. ¼ sec. 13, T. 21 S., R. 14 E. Basal beds.

4673. One mile southeast of Alcalde, at elevation of 1,600 feet on ridge west of 1,900-foot hill, center of NE. ¼ sec. 24, T. 21 S., R. 14 E. Basal beds.

4674. Halfway between West Coalinga and Commercial Petroleum wells, about 3 miles southwest of Coalinga. *Glycymeris* zone or basal beds. See locality 4660.

4675. About 2½ miles due west of Coalinga, at elevation of about 1,200 feet on road, north line of sec. 1, T. 21 S., R. 14 E. Lower middle beds.

4676. Six miles southeast of northwest end of Kettleman Hills, where old road crosses main ridge one-half mile east of 1,332-foot hill. Lower *Mya* zone, or lower middle beds.

4677. Ten miles southeast of northwest end of Kettleman Hills, on northeast side of summit of 1,370-foot hill, west side of NW. ¼ sec. 20, T. 22 S., R. 18 E. Lower *Mya* zone, or lower middle beds.

4678. On road north of locality 4676, one-half mile east-northeast of 1,332-foot hill. Lower middle beds.

4679. Area about 10 to 12 miles southeast of northwest end of Kettleman Hills; *Mulinia* beds on both sides of anticline, between 1,370-foot and 1,277-foot hills on main ridge and within 1 mile northeast of those hills on opposite side of anticline. Lower middle and basal beds.

4681. On east side of Kettleman Hills 3 miles northeast of Light's place in Avenal Gap, on southwest side of long, low ridge near axis of anticline, middle of west side of NE. ¼ sec. 4, T. 24 S., R. 19 E. Upper (?) *Mulinia* zone, or lower middle beds.

4682. One-third mile west of locality 4681, north-central part of NW. ¼ sec. 4, T. 24 S., R. 19 E. Upper *Mulinia* zone, or lower middle beds.

4683. South of Avenal Gap in Kettleman Hills; extremely fossiliferous sand on summit of 500-foot knob just north of old house, 2½ miles S. 45° E. of Light's place, northern part of NW. ¼ sec. 27, T. 24 S., R. 19 E. Upper *Mulinia* zone, or lower middle beds.

4684. South-central part of Kettleman Hills, about 5 miles northwest of Dudley-Lemoore road, in second main canyon 1¼ miles N. 45° E. of 1,030-foot hill, center of SW. ¼ sec. 35, T. 22 S., R. 18 E. Lower *Mulinia* zone, about 3,000 feet below top of Etchegoin; lower middle or basal beds.

4688. On Anticline Ridge, southwest of Turner well No. 2, middle of S. ½ sec. 2, T. 20 S., R. 15 E. Several hundred feet above base of Etchegoin, in the lower middle beds.

4690. Two miles southwest of Coalinga, south of Lucile well, SW. ¼ sec. 6. Lower middle beds.

4693. South-central part of Kettleman Hills, about 9 miles northwest of Avenal Gap, 1,000 feet northeast of 1,030-foot hill, SW. ¼ NE. ¼ sec. 3, T. 23 S., R. 18 E.; 950 feet stratigraphically below summit of Etchegoin. About the same as *Pecten coalingaensis* zone, or upper middle beds.

4695. East side of Kettleman Hills south of Avenal Gap, from gravelly surface of ground, NE. ¼ SE. ¼ sec. 27, T. 24 S., R. 19 E. Lower middle beds.

4696. About 2,000 feet east of main ridge of Kettleman Hills, 1 mile southeast of Light's place, SW. ¼ NW. ¼ sec. 21, T. 24 S., R. 19 E. In dark gypsiferous sand and clay about 750 feet stratigraphically below top of Etchegoin; probably the equivalent of the *Pecten coalingaensis* zone, or upper middle beds.

4697. Near south end of Kettleman Hills, along summit of ridge (elevation 592 feet) 4 miles S. about 20° E. of Light's place in Avenal Gap, on west side of sec. 3, T. 25 S., R. 19 E. Prominent pebble bed 1,600 to 2,000 feet below summit of Etchegoin. Probably same horizon as 4695, in lower middle beds.

4698. North of White Creek syncline, about three-fourths mile north of White Creek and 3¼ miles northwest of junction with Los Gatos Creek, in center of sec. 23, T. 19 S., R. 13 E. Upper middle beds.

4699. Eastern border of southernmost group of Kettleman Hills, in gray and blue sand on northeastern side of knoll in western part of sec. 26, T. 24 S., R. 19 E. About same horizon as 4695 and 4697, in lower middle beds.

4700. Kettleman Hills. Float. Undifferentiated lower or middle beds.

4701. East side of Kettleman Hills, at base of upper *Mya* zone or uppermost beds on Dudley-Lemoore road, in east-central part of sec. 17, T. 23 S., R. 19 E.

4702. South-central part of Kettleman Hills, on northwest side of 813-foot hill 4½ miles northwest of Avenal Gap, 400 feet east of main ridge where old road crosses, NW. ¼ NW ¼ sec. 25, T. 23 S., R. 18 E. Gypsiferous sand and pebble bed about 900 feet stratigraphically below summit of Etchegoin. Probably equivalent to *Pecten coalingaensis* zone, or upper middle beds.

4703. Central part of Kettleman Hills, 10 miles northwest of Avenal Gap, three-fourths mile N. 30° W. of 1,030-foot hill, SW. ¼ SW ¼ sec. 34, T. 22 S., R. 18 E. About 900 feet stratigraphically below summit of Etchegoin. Probably equivalent of *Pecten coalingaensis* zone, or upper middle beds.

4704. Central part of Kettleman Hills, 11 miles northwest of Avenal Gap, on south base of 1,145-foot hill, in the very southeast corner of sec. 28, T. 22 S., R. 18 E. Just above upper *Mulinia* zone, in lower middle beds.

4705. One-third mile south of B. M. 923 feet on Zapato Creek, from hard layers in sand forming a ridge that runs along 1 mile from there on south side of road to Canoas Creek, on west side of NW. ¼ sec. 17, T. 22 S., R. 16 E. About 450 feet below summit of Etchegoin. *Pecten coalingaensis* zone, or upper middle beds.

4706. Just across the gully east of the Call well, 7 miles north-northwest from Coalinga, in the northwest corner of sec. 32, T. 19 S., R. 15 E. Lower middle beds (?).

4707. About one-fourth mile northeast of Hugo Kreyenhagen's house, between two roads that run east from Canoas Creek, center of sec. 27, T. 22 S., R. 16 E. Sea-urchin bed immediately above upper *Mulinia* zone, about 900 feet stratigraphically above base of Etchegoin, in lower middle beds.

4708. 1,245-foot hill 4 miles southeast of northwest end of Kettleman Hills, east side of sec. 32, T. 21 S., R. 17 E. *Arca* bed in upper *Mya* zone, or uppermost beds.

4709. East side of Kettleman Hills, on summit of ridge in center of SE. ¼ sec. 6, T. 22 S., R. 18 E. Drab sand with hard sandstone layers, 750 to 800 feet stratigraphically below summit of Etchegoin. *Pecten coalingaensis* zone, or upper middle beds.

4710. Three-fourths of a mile northwest of Zapato Creek B. M. 806 feet, on north side of ravine, west-central part of NE. ¼ sec. 5, T. 22 S., R. 16 E. *Pecten coalingaensis* zone, or upper middle beds.

4711. West side of 1,245-foot hill 4 miles southeast of northwest end of Kettleman Hills, central part of sec. 32, T. 21 S., R. 17 E. Oyster bed 50 feet above *Arca* bed of locality 4708. Upper *Mya* zone, or uppermost beds.

4712. East of Zapato Creek, one-half mile south of Adolph Kreyenhagen's house, SW. ¼ SE. ¼ sec. 8, T. 22 S., R. 16 E. Variable pebbly sand, with many fossils. *Pecten coalingaensis* zone, or upper middle beds.

4713. About 5½ miles southeast of northwest end of Kettleman Hills, on top of 1,332-foot hill in south-central part of sec. 3, T. 22 S., R. 17 E. Sand-dollar bed of drab sand overlying blue and gray sand of lower *Mya* zone, both being in the lower middle beds.

4714. Two miles southwest of Coalinga, at elevation of 900 feet, near edge of Alcalde Hills, on ridge descending east from prominent hill (elevation 1,410 feet), just east of center of SW. ¼ sec. 6, T. 21 S., R. 15 E. Coarse sand and pebble conglomerate about 650 feet stratigraphically above base of Etchegoin. *Pecten coalingaensis* zone, or upper middle beds.

4715. South end of Kettleman Hills, sec. 10, T. 25 S., R. 19 E. Upper middle and uppermost Etchegoin beds.

4716. Near northwest end of Kettleman Hills, 2 miles north-northwest of 1,245-foot hill, east of center of SW. ¼ sec. 20, T. 21 S., R. 17 E. In sand just below flinty white shale bed that marks top of Etchegoin. Just below 4740. Upper *Mya* zone, or uppermost beds.

4717. Near northwest end of Kettleman Hills, 1¾ miles northwest of 1,245-foot hill, just east of old house, northwest corner of sec. 29, T. 21 S., R. 17 E. *Arca* sand below white shale at top of Etchegoin, upper *Mya* zone, or uppermost beds.

4718. Main ridge of Kettleman Hills, 4 miles north of Dudley-Lemoore road, on summit of 1,020-foot hill, east side of sec. 11, T. 23 S., R. 18 E. Upper *Mya* zone, or uppermost beds.

4720. One mile due north of Light's place in Avenal Gap, on south side of hill (elevation 555 feet) in center of SW. ¼ sec. 8, T. 24 S., R. 19 E. Very gypsiferous sand at base of upper *Mya* zone, or uppermost beds.

4722. Three-fourths mile southeast of Adolph Kreyenhagen's on Zapato Creek, northwest corner of sec. 16, T. 22 S., R. 16 E. Upper *Mya* zone, or uppermost beds.

4723. South group of Kettleman Hills, on point of main ridge facing Avenal Gap one-half mile east-southeast of Light's place, south side of SE. ¼ sec. 17, T. 24 S., R. 19 E. Upper *Mya* zone, or uppermost beds.

4724. Main ridge of south group of Kettleman Hills, 1 mile south of Avenal Gap, NW. ¼ SE. ¼ sec. 20, T. 24 S., R. 19 E. Upper *Mya* zone, or uppermost beds.

4725. East side of Kettleman Hills, on 500-foot ridge at contact of Etchegoin and Tulare north of sharp turn in Dudley-Lemoore road, southwest corner of sec. 8, T. 23 S., R. 19 E. Upper *Mya* zone, or uppermost beds.

4728. On northeast border of Kettleman Hills, on southwest flank of 900-foot hill just east of old road, in north part of sec. 35, T. 21 S., R. 17 E. Upper *Mya* zone at top of Etchegoin immediately underlying Tulare fresh-water beds of 4731.

4729. About 1½ miles east of Garza Creek, just north of road, at west foot of hill (elevation 1,174 feet), southeast corner of NE. ¼ sec. 36, T. 22 S., R. 16 E. Upper *Mya* zone, or uppermost beds.

4730. Central part of Kettleman Hills, on summit of 1,030-foot hill on main ridge 9¼ miles northwest of Light's place in Avenal Gap, center of sec. 3, T. 23 S., R. 18 E. Upper *Mya* zone, or uppermost beds.

4736. East side of Kettleman Hills, east of Dudley-Lemoore road, NE. ¼ SW. ¼ sec. 17, T. 23 S., R. 19 E. Upper *Mya* zone just below fresh-water bed (Tulare) of locality 4737, uppermost beds.

4741. In Kettleman Hills, 3½ miles north of Dudley-Lemoore road on little hill (elevation 600+ feet), northeast corner of sec. 12, T. 23 S., R. 18 E. In lower middle beds just above lower *Mya* zone.

4744. West of Canoas Creek, north of road leading to Zapato Creek, SW. ¼ NW. ¼ sec. 22, T. 22 S., R. 16 E. Upper *Mya* zone, uppermost beds.

4749. On ridge east of Garza Creek, in NE. ¼ sec. 1, T. 23 S., R. 16 E. Lower *Mulinia* zone, basal beds of Etchegoin.

4750. On ridge east of Garza Creek, about 1,200 feet stratigraphically above 4749, SW. ¼ sec. 36, T. 22 S., R. 16 E. Lower middle beds.

4751. On ridge east of Garza Creek and immediately west of road from Garza Creek to Big Tar Canyon, NW. ¼ sec. 36, T. 22 S., R. 16 E. About 1,000 feet stratigraphically above 4750, or in upper middle beds.

4752. On ridge east of Garza Creek and immediately northeast of road connecting Garza Creek and Big Tar Canyon, NE. ¼ sec. 36, T. 22 S., R. 16 E. Upper *Mya* zone, about 1,000 feet stratigraphically above 4751, uppermost beds.

4753. On Waltham Creek 13 miles southwest of Coalinga, 200 yards north of Elmer Frame's house. In gray sandstone well up in Etchegoin formation, probably in middle beds.

4754. Waltham Creek, 13 miles southwest of Coalinga, three-fourths mile east of Elmer Frame's place. Gray sandstone 200 feet stratigraphically below 3849; probably in middle beds.

4755. About 4 miles south of Coalinga in Jacalitos Hills, SW. ¼ sec. 21, T. 21 S., R. 15 E. Undifferentiated lower or middle beds.

4756. Vicinity of Henry Spring, 4 miles south-southwest of Coalinga, on east side of 1,900-foot hill, SW. ¼ sec. 18, T. 21 S., R. 15 E. Lower middle or basal beds.

4757. Same locality, but 150 feet stratigraphically above 4756. Lower middle or basal beds.

4758. Same locality, but 490 feet stratigraphically above 4756. Upper middle beds.

4759. Same locality, but 500 to 900 feet stratigraphically above 4756. Upper middle beds.

4760. On old road crossing north end of Kettleman Hills, three-fourths mile northeast of 1,332-foot hill, SE. ¼ NW. ¼ sec. 2, T. 22 S., R. 17 E. In lower middle beds 1,900 feet stratigraphically below summit of Etchegoin. About equivalent of lower *Mya* zone.

4761. On ridge one-half mile south of junction of Jacalitos and Salt creeks, southeast corner sec. 31, T. 21 S., R. 15 E. *Cardium* bed at base of Etchegoin; about equivalent of *Glycymeris* zone; basal beds.

4762. Southwest of Coalinga district, in Waltham Valley, three-fourths mile east of Elmer Frame's house. *Arca* and *Mactra* bed, probably basal beds.

4763. Southwest of Coalinga district, on Stone Canyon-Waltham Creek road just west of Waltham Valley. Probably middle beds.

4769. On east side of Canoas Creek just south of Hugo Kreyenhagen's home, northwest corner of SW. ¼ sec. 27, T. 22 S., R. 16 E. Probable equivalent of the *Glycymeris* zone, or lower *Mulinia* zone, at contact between Etchegoin and Jacalitos.

4778. About three-fourths mile east of Adolph Kreyenhagen's house on Zapato Creek, west side of sec. 9, T. 22 S., R. 16 E. Small *Ostrea* bed, about 100 feet stratigraphically below *Mya* bed at top of Etchegoin formation in upper *Mya* zone.

4780. One-fourth mile west of locality 4778. *Arca* bed about 350 feet below summit of Etchegoin, in upper beds.

4781. Arcas from north-central part of Kettleman Hills. Basal *Mulinia* beds.

4782. On southwest flank of high hill (elevation 1,458 feet) east of lower part of Canoas Creek, at elevation of 1,200 feet, SW. ¼ SW. ¼ sec. 23, T. 22 S., R. 16 E. Upper *Mya* zone, or uppermost beds.

4783. On the northwest bank of Canoas Creek, three-fourths mile below H. Kreyenhagen's, 16 miles southeast of Coalinga, northeast corner of SW. ¼ sec. 22, T. 22 S., R. 16 E. In *Ostrea* bed 125 feet stratigraphically below the top of the Etchegoin formation, in uppermost beds.

4799. Coalinga district; exact locality unknown.

4806. Two miles southeast of Coalinga, on north side of Alcalde Canyon, center of SW. ¼ sec. 7, T. 21 S., R. 15 E. *Glycymeris* zone, near base of Etchegoin.

4857. Extreme southeast end of Kettleman Hills, in secs. 11 and 12, T. 25 S., R. 19 E. *Pecten owenî* bed, probably lowest Etchegoin.

FAUNAL ZONES.

The lowest fossiliferous bed in the Etchegoin is in a zone in which *Glycymeris coalingensis* Arnold and *G. septentrionalis* Middendorf are exceedingly abundant; this zone is called the *Glycymeris* zone. Above this are beds in which *Mulinia densata* Conrad is very abundant; this is the upper *Mulinia* zone. Still higher in certain parts of the field *Echinarachnius gibbsii* Rémond is very common, but other fossils rare, and this is sometimes called the *Echinarachnius* zone. A few hundred feet below the top of the Etchegoin is an exceedingly fossiliferous zone in which *Pecten coalingaensis* Arnold is a common species, and this is called the *Pecten coalingaensis* zone; above it and practically at the top of the Etchegoin is the upper *Mya* zone, characterized by numerous *Mya japonica* Jay. In the Kettleman Hills is another zone between the *Mulinia* and *Pecten coalingaensis* zones, in which *Mya japonica* Jay is practically the only fossil; this is called the lower *Mya* zone.

The *Glycymeris* zone, or zone of the basal beds, is characterized by the two species of this genus previously mentioned, *Diplodonta harfordi* F. M. Anderson, *D. parilis* Conrad, *Cardium meekianum* Gabb, and *Pecten owenî* Arnold. Locality 4806 is typical of this zone. The localities representative of this zone are Nos. 4648, 4656, 4657, 4658, 4659, 4660, 4661, 4662, 4663, 4664, 4665, 4669, 4672, 4673, 4674, 4679 (in part), 4684, 4749, 4756, 4757, 4761, 4762, 4769, 4781, 4806, and 4857.

The upper *Mulinia* zone, or zone of the lower middle beds, contains numerous *Mulinia densata* Conrad, *Ostrea atwoodi* Gabb, and *Arca trilineata* Conrad. It is represented by the following localities: Nos. 4643, 4671, 4675, 4676, 4677, 4678, 4679 (in part), 4681, 4682, 4683, 4688, 4690 (?), 4695, 4697, 4699, 4704, 4706 (?), 4707, 4713, 4741, 4750, and 4760.

The *Pecten coalingaensis* zone, or zone of the upper middle beds, is characterized by *Pecten coalingaensis* Arnold, *P. wattsi* Arnold and its variety *etchegoini* F. M. Anderson, *Terebratalia smithi* Arnold, and *Ostrea vespertina* Conrad. Locality 4712 yields a fauna typical of this horizon. It is also represented by the following localities: Nos. 4693, 4696, 4698, 4702, 4703, 4705, 4709, 4710, 4712, 4714, 4715 (in part), 4751, 4758, and 4759.

The upper *Mya* zone, or zone of the uppermost Etchegoin beds, carries *Mya japonica* Jay, *Littorina mariana* Arnold and its variety *alta* Arnold, *Trochita filosa* Gabb, and *Solen sicarius* Gould. Just above the upper *Mya* zone is usually found a bed in which are numerous *Ostrea vespertina* Conrad var. *sequens* Arnold. This zone is represented at the following fossiliferous localities: Nos. 4670, 4701, 4708, 4711, 4715 (in part), 4716, 4717, 4718, 4720, 4722, 4723, 4724, 4725, 4728, 4729, 4730, 4736, 4744, 4752, 4778, 4780, 4782, and 4783.

The following localities are undifferentiated: Nos. 3849, 4700, 4753, 4754, 4755, 4763, and 4799.

ORIGIN OF THE ETCHEGOIN.

A study of the faunas of the various zones of the Etchegoin leads to some interesting conclusions concerning the physical conditions under which the strata were deposited at various times throughout the Etchegoin epoch, and also to some important correlations, not only with formations in other parts of the Coast Range but with horizons of the Tertiary of the Eastern States.

The abundance of *Arca* in the *Glycymeris* and *Mulinia* zones leads to the conclusion that the water in which the lower part of the Etchegoin was laid down was somewhat warmer than that now prevalent on the Pacific coast at the latitude of Coalinga.

Following the deposition of the two lower zones came a period in which estuarine conditions prevailed over at least a part of the Coalinga shore line, for in the Kettleman Hills is a bed in which are to be found large numbers of *Mya japonica* Jay, a noted cold-water species preferring mud flats. This *Mya* bed in turn is followed by strata in which is a fauna having many characteristics in common with the fauna of the Gulf of California province, a province that has been subject to tropical conditions at least since the beginning of Miocene time. It is therefore reasonable to suppose that a subsidence and change of conditions to those favoring the immigration of warmer-water species took place some time after the deposition of the middle Etchegoin. These conditions were suddenly altered near the close of the Etchegoin epoch, as is indicated by the fauna of the upper *Mya* zone, which contains *Mya japonica*, *Macoma inquinata*, and *Littorina mariana* (closely allied to the northern *L. grandis* Midd.), species supposed to have been best suited to cold-water and possibly

estuarine conditions. It is a noteworthy fact in connection with this late Etchegoin cold-water invasion that it exterminated most of the species found in the subjacent beds, at least for the local Coalinga province, and that *Ostrea vespertina* Conrad, the only important species of the preceding fauna which persisted into the last part of the Etchegoin, was so adversely influenced by the new conditions that it became a dwarf of its former self and took up new characteristics at least of varietal importance. The uppermost Etchegoin representative of the beautiful well-developed *Ostrea vespertina* is the dwarfed, thin variety *sequens*.

Other evidence showing the varying conditions which prevailed during the latter half of the Etchegoin is to be found in the occurrence within the formation of curious bulbous growths of fishes, such as are later mentioned as occurring associated with the fresh-water fossils in the basal Tulare. The lowest horizon at which they were found is at locality 4697, from 1,600 to 2,000 feet below the summit of the formation. These occur alone, with marine fossils, or with fresh-water fossils. At one horizon about 900 feet below the summit of the Etchegoin, along the eastern foot of the main ridge in the southern portion of the Kettleman Hills, abundant specimens of *Goniobasis*, a fresh-water genus, were found in gypsiferous beds associated with the curious fish bones. This horizon is represented by locality 4696, and is about equivalent to that of *Pecten coalingaensis*. These bones and shells indicate that a close connection existed between areas of salt water and nearly if not entirely fresh water during much of the Etchegoin period, and that, especially in the later portion of the period, conditions were on the verge of becoming such as existed during early Tulare time. The great thickness of inky-blue fine clay in the upper portion of the Etchegoin of the Kettleman Hills below the sands of the upper *Mya* zone is believed to have originated as fine delta deposits, possibly subaerially and above the reach of the tide.

The presence of enormous quantities of *Echinarachnius*, accompanied by no other fossils, in some of the middle or upper middle Etchegoin sands and of somewhat similar deposits in the upper Jacalitos indicates that at various periods throughout the upper Miocene extensive shallow sand flats prevailed along the edge of the San Joaquin sea.

CORRELATION AND AGE.

F. M. Anderson[a] correlates the typical San Pablo beds of the Mount Diablo province with the lower portion of the Etchegoin, and this correlation agrees in general with that made by the writers. To be more exact, it is believed that the upper Jacalitos and lower Etchegoin are probably the equivalent of the typical San Pablo, and that

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, p. 180.

the upper Etchegoin is possibly younger than the latest San Pablo and agrees in age more nearly with the lower part of the fossiliferous Purisima formation on the southwestern flanks of the Santa Cruz Mountains.[a]

The similarity of the fauna of the upper Etchegoin to the fauna of the latest marine formation in the Carrizo Creek district of eastern San Diego County and similar beds at Santa Rosalia and other points in Lower California has led the writers to correlate the latter with the Etchegoin, and on the basis of this correlation to suppose that the upper Miocene sea occupied the upper end of the Gulf of California depression. This last correlation is in agreement with that of Gabb and Cooper, who considered the bed of Carrizo Creek to be Pliocene (some of their Pliocene now being recognized as upper Miocene by the writers). The number of species common to the two faunas is not large, but the abundance of the individuals and the uniqueness of the forms compensate for this. Among the forms common to the two faunas are *Ostrea vespertina* Conrad, *Pecten deserti* Conrad, and *Neverita recluziana* Petit.

The similarity of *Ostrea vespertina* Conrad, *Mytilus* (*Mytiloconcha*) *coalingensis* Arnold, and *Pecten deserti* Conrad, of the Etchegoin fauna, to *Ostrea sculpturata* Conrad, *Mytilus* (*Mytiloconcha*) *incurvus* Conrad, and *Pecten gibbus* Linnæus var. *concentricus* Say, of the Miocene and Pliocene of the Atlantic States, points strongly to a direct connection between the Atlantic and Pacific provinces during the Miocene. If such a connection existed it was possibly through southern Arizona and New Mexico and thence along the course of the Rio Grande to the Gulf of Mexico, although it might have been farther south.

The age of the Etchegoin in terms of the standard time scale is now, and probably will be for some time to come, a question on which opinions differ. F. M. Anderson and the writers agree on the general correlation of the San Pablo and Etchegoin; about this there can be very little doubt. But when it comes to assigning the San Pablo and Etchegoin to the Pliocene, the writers differ with Anderson[b] and also with Weaver.[c]

According to the list found in this paper the Etchegoin is represented by 84 recognizable species. Of these, 55 species or varieties, or 65 per cent, are extinct, while but 29 species, or 35 per cent, are still living in the Pacific Ocean. According to Lyell's classification this would place the formation decidedly in the Miocene. Furthermore, of the fauna of 18 recognizable species at locality 4712, a fauna typical of the upper part of the Etchegoin, 16 species and varieties,

[a] Arnold, Ralph, Proc. U. S. Nat. Mus., vol. 34, 1908, p. 353.

[b] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, pp. 180 et seq.; idem, 4th ser., vol. 3, pp. 28 et seq.

[c] Bull. Dept. Geology Univ. California, vol. 5, p. 269.

or 89 per cent, are extinct and only 2 species, or 11 per cent, are now living.

In addition to the evidence presented above, which at best is largely dependent upon the personal interpretation of the meaning of species, there is the evidence of the position of the Etchegoin in the geologic series of California. An examination of its fauna indicates that its upper portion is equivalent to the lowest Purisima of the western side of the Santa Cruz Mountains, and there is no question that in places at least 4,000 or 5,000 feet[a] of strata separate this lower Purisima fauna from the lower Merced fauna, and that between 3,000 and 5,000 feet of Merced (both Pliocene and Pleistocene) overlie the lower Merced fauna. Therefore it is evident that since the deposition of the Etchegoin enough time has elapsed for the deposition of between 7,000 and 10,000 feet of strata on the California coast. Taking 25,000 feet as a conservative estimate of the total maximum thickness of the Tertiary on the west coast, the 7,000 to 10,000 feet of strata above the Etchegoin would place the top of the Etchegoin at least a third of the way down toward the base of the Tertiary. Hence, by this line of reasoning also, it seems more consistent to place the Etchegoin in the Miocene than in the Pliocene.

IMPORTANCE WITH RELATION TO PETROLEUM.

The Etchegoin formation is nowhere within the Coalinga district known to contain any petroleum, but like the Jacalitos it has an important relation to the question of accessibility of the oil. Some wells in the Coalinga field pass through a considerable portion or the whole of this formation before reaching the Jacalitos or lower formations. All wells drilled around the edge of Pleasant Valley, or on Anticline Ridge, or in the Kettleman Hills will have to pass through this formation, and its thickness must be taken into account in calculating the depth of the oil sands. The great increase in thickness south of Waltham Creek, in this and the other post-Eocene formations, has an all-important bearing on such calculations.

TULARE FORMATION (UPPER PLIOCENE-LOWER PLEISTOCENE).[b]

DEFINITION AND GENERAL DESCRIPTION.

The Etchegoin is overlain along the border of the valley by the Tulare formation, a thick terrane of bedded but little-consolidated gravel, sand, and clay, with occasional indurated layers throughout and with associated beds of fresh-water shells, marl, and limestone at the base. This terrane is the uppermost member of the series

[a] See Santa Cruz folio (No. 163), Geol. Atlas U. S., U. S. Geol. Survey, 1909.

[b] Described in the preliminary report on this district, Bull. U. S. Geol. Survey No. 357, under the name Paso Robles formation.

of upturned formations exposed in the monocline on the eastern flank of the Diablo Range. It differs materially from the formations so far described in that the origin of its greater portion is doubtful, being in part fresh water, in part marine, and in part probably subaerial. In the Kettleman Hills, where these beds are best exposed, the basal sand, which appears to lie conformably upon the marine bed at the top of the Etchegoin, contains many fresh-water fossils. The beds above this have a thickness of several thousand feet, and as far as observed are nonfossiliferous except at one horizon near the summit, at which a few marine fossils have been found. (See fossil locality 4743.) Along the foothills west and northwest of the Kettleman Hills the basal fresh-water beds have not been recognized and may be lacking. There gravel and sand beds belonging to the same series overlie the Etchegoin with local appearances of unconformity.

This whole series of tilted beds overlying the Etchegoin is here referred to and mapped as one formation for the reason that it appears to be a continuous succession and can not be consistently subdivided. It was formed under varying conditions of deposition, but the indications are that it represents a nearly continuous if not wholly uninterrupted period. Its accumulation began in the Pliocene epoch, probably in the earlier portion, and is thought to have continued into the Pleistocene. Its summit may be considered as the highest bed markedly displaced from its original attitude by the uplift which threw the formation into folds. It is unconformably overlain by the more recent horizontal terrace deposits and alluvium.

The highest exposed portion of the formation appears near the edge of Kettleman Plain, in the south-central part of the Kettleman Hills, but the summit of the formation as above defined does not outcrop. It is probable, however, that the edge of the hills there marks the approximate summit of the tilted beds. The formation may be recognized most easily by the fresh-water fossils and strange bone beds at its base, to be described more fully below, by its marginal position along the valley, and by the prevalence in it of prominent beds of bowlder gravel, which is more coarse and abundant than in any of the other Tertiary formations. Otherwise this formation resembles some of the others closely, and it is in many places difficult to differentiate them.

PREVIOUS DESCRIPTIONS.

This formation was named Tulare by Frank M. Anderson in his paper entitled "A stratigraphic study in the Mount Diablo Range of California."[a] He stated that it is a fresh-water formation fully

[a] Proc. California Acad. Sci., Geology, vol. 2, 1905, No. 2.

1,000 feet thick lying conformably upon the Etchegoin formation in the Kettleman Hills. It was originally mentioned by W. L. Watts,[a] who gave a section of the beds and included a list of the fresh-water shells collected from them by him and identified by J. G. Cooper. He described the occurrence of similar fresh-water deposits in the region of McKittrick farther south, which are possibly to be correlated with these. In the same year Cooper described the fossils collected by Watts in these deposits and gave notes on their occurrence.[b]

The formation here described as the Tulare was referred to in the preliminary report on the Coalinga district[c] as the "Paso Robles," owing to its supposed equivalence to that formation, which had been named[d] earlier than the Tulare. The correlation was based upon the similarity in stratigraphic position and lithology of the beds in the Coalinga district to those spreading over the summit region of the Temblor Range, between the Polonio and Palo Prieto passes, about 15 miles southwest of the southernmost exposures in the Kettleman Hills. These beds in the Temblor Range seemed to be continuous with and to answer the description given by Fairbanks of the Paso Robles formation in the Salinas Valley. The formation there was originally named from the town of Paso Robles, and described as a probably fresh-water Pliocene formation of unconsolidated beds at least 1,000 feet thick, spreading widely over the Salinas drainage area and extending nearly or quite to the divide (the Temblor Range) between Estrella River and the San Joaquin Valley. It was stated by Fairbanks to lie unconformably upon the San Pablo formation, by which was meant the Santa Margarita.

Subsequent study of the Salinas Valley deposits, carried on by the junior author during the autumn of 1908, has shown that at least the lower portion of the beds there to which the name Paso Robles was applied are of marine origin and equivalent to a part of the upper Miocene succession in the Coalinga district described in the present paper as Jacalitos and Etchegoin. As yet no fossils have been found in the upper portion of the Paso Robles formation, and this portion may prove to be of fresh-water origin, as stated in Fairbanks's original description, but in view of the fact that no stratigraphic break in the succession of Paso Robles beds has been found, the discovery of the marine origin and the approximately San Pablo age of the lower portion tends to cast doubt upon the propriety of the adoption of the name Paso Robles in the Coalinga field. It is not certain that the upper portion of the Paso Robles

[a] The gas and petroleum yielding formations of the central valley of California: Bull. California State Min. Bur. No. 3, 1894, pp. 55, 67.

[b] Proc. California Acad. Sci., 2d ser., vol. 4, 1894, pp. 167–169.

[c] Bull. U. S. Geol. Survey No. 357, 1908.

[d] Fairbanks, H. W., San Luis folio (No. 101), Geol. Atlas U. S., U. S. Geol. Survey, 1904.

formation farther west is equivalent to any part of the post-Etchegoin formation in the Coalinga district; and at any rate this portion has a thickness of but a few hundred feet at most, so that it could hardly represent a great part of the important formation in the Coalinga district. Hence the designation of this formation as the Tulare is appropriate.

DISTRIBUTION AND LOCAL CHARACTER.

TULARE IN THE KETTLEMAN HILLS.

The area covered by the Kettleman Hills is the only one in which the Tulare is at all completely exposed. This area therefore forms the basis for most of the discussion of the formation given here and may be considered as the type locality. As shown on the map, the Tulare occupies an almost complete fringe around the hills, dipping steeply away on the flanks of the anticline which exposes the Etchegoin beneath. Throughout the Kettleman Hills the Etchegoin and Tulare formations are apparently conformable, and in places there are indications that a gradual change took place toward the end of the deposition of the former, that shallow-water marine conditions gave way to brackish water, and these in turn to fresh-water conditions. In some places, at least, the estuarine upper *Mya* beds which are constant at the summit of the Etchegoin appear to grade into the fresh-water beds above.

As an example, a characteristic occurrence at the northern corner of the hills (at fossil localities 4716 and 4740) may be described. There a thickness of about 75 feet at the summit of the Etchegoin consists of unconsolidated fine gypsiferous sand containing at the base a great many Arcas, etc., and at the top an abundance of delicate little oysters in fine grayish-white, ashlike sand and earthy, sandy clay full of gypsum. The oyster sand is overlain by and seems almost to grade into a bed a few feet thick of brittle, porcelaneous and opaline, black, brown, gray, and variously colored siliceous shale that weathers to a bluish-white tint and is locally soft and chalklike. It bears some resemblance to the "indicator" bed in the Vaqueros north of Coalinga and to the various other occurrences of diatomaceous and porcelaneous shale already cited, but it is not certain that it had a similar origin. This bed is overlain by a zone of sand and pebbles about 20 feet thick that is full of strangely shaped flinty fossil bones of purplish and black color. Three varieties of these are shown in Plate LII. Some of these bones have been recognized, with the aid of Mr. J. W. Gidley, of the United States National Museum, Dr. D. S. Jordan, of Stanford University, and Dr. J. C. Merriam, of the University of California, as being the bulbous growth from the anterior portion of the back or the anterior end of the ventral fin, and others as spines of some fish or different

fishes. Not even the order to which these belong is determinable and they may be either marine or fresh-water fishes. Some associated petrified fragments resemble copralites, and there are likewise fragments closely resembling the teeth of mammals. Bones of the same character have been mentioned as associated with both marine and fresh-water fossils in the Etchegoin (fossil localities 4695, 4696, 4697, 4699, and 4741). Associated with the bones in the locality that is being described are minute fresh-water gasteropods, and one small oyster similar to those in the beds below was found on the surface together with the other fossils. If oysters are in place in this bed they indicate an alternation of brackish and fresh water conditions. Just above the bed with bones and other fossils comes a zone of fine gray sand with scattered pebbles and some clay full of fresh-water shells, such as *Anodonta*, etc., and containing likewise specimens of the strange bones in smaller numbers than the bed below. Above this fresh-water zone, which is here altogether about 100 feet thick, the formation is not fossiliferous.

The preceding paragraph describes the contact zone between the Etchegoin and Tulare formations as it occurs at one place in the northern part of the Kettleman Hills, and although minor variations are to be found at every other locality the essential points are the same. As this description shows, the division is no sharp one and it is possible that a gradual change to fresh-water conditions took place and that the formations intergrade. The line of contact between the two formations is drawn at the top of the porcelaneous shale bed because that bed appears to be represented farther southeast by a bed of soft white sand containing oyster shells. In the central and southeastern portions of the Kettleman Hills this contact bed of shale has not been recognized definitely, but the upper *Mya* beds are at many places characterized by the inclusion of layers of white siliceous shale that may represent a similar process of deposition. The succession of fossils in the *Mya* beds is not everywhere as given in the paragraph above, the oysters in some localities, notably farther south in the Kettleman Hills, being absent at the top and more abundant below the beds with *Mya*, *Arca*, *Littorina*, etc. It is also true that a fossil bed does not everywhere come within a few feet below the fresh-water beds, as for instance in the central and south-central part of the hills, where a zone of inky-blue clay over 50 feet in thickness intervenes between the beds with *Mya*, etc., and those with fresh-water shells. Nor does the bed full of strange bones generally come below the *Anodonta* bed. The latter is more commonly found immediately overlying the *Mya* and oyster beds, and the pebble beds with bones, in turn, lie above this. The contact zone is locally marked by thin hard beds of limestone and hardened sandstone formed of the fresh-water fossils,

and an earthy rock with oolitic structure due to the small gasteropods that make up more than half its bulk. Beds of this character at the contact form the high ridge or line of hills that parallels the valley for much of the way along the northeast flank of the Kettleman Hills (fossil localities 4721 and 4731).

The thickness of the basal fossiliferous zone of the Tulare is usually no more than 60 to 100 feet, although it is as much as 300 feet on the southeast side of the Kettleman Hills a few miles northeast of Avenal Gap. These variations from place to place indicate the variable shallow-water conditions of deposition that prevailed at the beginning of Tulare time; yet the constancy over at least the whole area occupied by the Kettleman Hills of the estuarine and perhaps brackish-water fauna at the top of the Etchegoin and of the fresh-water fauna just above it shows over what extent the continuous deposition of the material of each of these zones took place.

The only fossils found in the Tulare at a higher horizon than the basal zone are of marine origin and occur in the upper portion of the formation (fossil locality 4743). Their stratigraphic position is shown in the tabulated section given below (p. 147).

Above the basal zone the Tulare formation consists of a continuous unvaried succession of alternating zones and beds of unconsolidated light-gray and yellowish fine sand, sandy clay, light and dark clay, coarse darker-gray sand, gravel and bowlder beds, and occasionally interbedded layers of hard sandstone. The whole series is gypsiferous. The beds are usually fairly thick and massive and the bedding planes not very pronounced, although in some places the strata are sharp and square cut. Frequently the stratification and the dip appear more distinct from a distance than from near at hand. Many of the coarse sand and gravel deposits are roughly stratified and exhibit lenticular structure, grading within a short distance into finer deposits. In general, the formation resembles very closely the recent alluvial deposits and is almost indistinguishable from them except by the disturbed position of its beds.

A marked feature of the gravel is the predominance in it of subangular fragments of hard white siliceous shale derived presumably from the shale either of the Tejon or of the Santa Margarita (?) formation. This shale is very resistant and lends itself remarkably to preservation in younger deposits of gravel and débris.

The gravel deposits southwest of the Coalinga district, along the Temblor Range south and west of Antelope Valley, which are believed to be equivalent in age to the Tulare, are likewise characterized by the predominance of inclusions of similar shale. On the Temblor Range this shale comes from the formation that is continuous with the Santa Margarita (?) described along Reef Ridge, and it is there-

fore probable that the Tulare in the Coalinga district derives at least a large part of the shale pebbles from that formation. These pebbles have in general been subjected to only a moderate amount of erosion and resemble in this respect the similar fragments derived from the Santa Margarita (?) that are abundant in the recent alluvial deposits and are scattered over the surface of the country both near and far away from their source.

The other pebbles and bowlders in the gravel beds of the Tulare are of many different types of rock and were probably derived chiefly from the Coast Ranges. Many of them are angular and have been subjected to little wear before being deposited. Rocks of a granitic type are very common, and also serpentine, porphyries of different kinds, several varieties of basic igneous rocks, both fresh and considerably altered, jasper, sandstone, conglomerate, quartz, schist, etc.

On the summit of the most southwesterly ridge of the Kettleman Hills bowld rs full of fossils characteristic of the Vaqueros beds on Reef Ridge, particularly *Pecten andersoni*, were found in the Tulare formation. Bowlders of exactly the same type are common in the upper *Mya* zone at the top of the Etchegoin, and this may be taken as a further indication of the close relationship between the summit beds of the Etchegoin and the Tulare, inasmuch as the materials were derived from the same source and, to judge by these bowlders, from almost exactly the same locality. These bowlders give a good illustration of the profound unconformity existing between the Vaqueros and these later Tertiary formations. The siliceous-shale fragments are likewise common in the upper Etchegoin, although not present, as far as observation has gone, in the earlier beds, which proves that the original shale formation, probably the Santa Margarita (?), was exposed to erosion during at least the later Etchegoin and the Tulare periods.

The lower beds of the Tulare in the Kettleman Hills are, as a rule, not of very coarse material, although pebbles are scattered through them. The first important zone of coarse gravel appears several hundred feet above the base. It is associated with several beds of hard sandstone and in consequence shows a marked influence on the topography, forming a hill on each of the lateral ridges descending from the summit to the valley. These may be distinguished upon the topographic map. This zone probably occurs at a slightly variable horizon, ranging from about 500 to 800 feet above the base of the formation. It is in general higher toward the south and may thus indicate a thickening of the formation in that direction. Above this zone are various other prominent gravel zones.

The following tabular sections represent the character of the formation in that part of the Coalinga district in which it is most completely exposed. In each place the section was started at the edge

of the Kettleman Hills, but beds were not found exposed for about 700 feet into the hills away from the edge. In this border area the beds almost certainly have a fairly steep dip, and it would be conservative to add at least 150 feet to the total thickness given to represent the summit beds there.

The first section was made on the southwest side of the hills, about 9 miles northwest of Avenal Gap, and is as follows:

Section of Tulare formation 9 miles northwest of Avenal Gap.

	Feet.
Mostly fine, earthy, drab, and yellowish-gray, faintly bedded, massive sand, with occasional roughly aggregated beds and lenses of pebbles and bowlders; the stratification is very apparent from a distance	500
Similar beds of hard and compact straw-colored massive sandy clay, with partings of gypsiferous sandstone	300
Similar clay interbedded with pure sand, gravelly sand, and sandstone layers, with a hard sandstone bed at base	75
Compact drab, gray, and straw-colored coarse and fine sand	200
Thin layers of gravel and coarse sands with a bowlder bed several feet thick at base	75
Pure fine sand similar to that above, with hard sandstone layers	125
Mostly gravel composed in large part of fragments of hard white siliceous shale, interbedded with sand and sandy clay, and with hard sandstone beds at top and base	75
Alternating beds, from a few inches to 1 or 2 feet thick, of loose and compact fine sand, roughly bedded, slightly gritty clay, pebbly sand, gravel, and hard, usually purplish sandstone; some of the sand is speckled all over with inclusions of hard white siliceous shale and the gravel is largely composed of it	225
Pure clay and sandy clay	75
Fine clay and sand at top, grading down to coarse sand and pebble and bowlder beds at base; some fine drab sand forms hard, massive, roughly laminated beds	75
Drab sand with some pebbles and with gravel and hard sandstone beds at base	150
Sand and clay and a few hard sandstone beds	375
Gravelly sand	100
Loose earthy sand full of pebbles, bowlders, and fragments of white siliceous shale and containing fresh-water shells and bones; at the base is a sharp change to the dark clay and upper *Mya* beds of the Etchegoin	50
	2,400

The following section was made on the southwest flank of the Kettleman Hills along the Dudley-Lemoore road, which crosses about 4 miles northwest of Avenal Gap:

Section of Tulare formation along Dudley-Lemoore road.

	Feet.
Massive 1 to 3 foot beds of well-compacted but not indurated fine sand, clayey sand, clay, coarse sand, and gravelly sand, with several beds, many feet thick, of coarse gravels and bowlders in the middle and at the base. Much gypsum occurs in fine particles and as a filling in cracks, causing hardening in individual beds and in spots. Some sand and gravel beds are lenticular. One hundred feet below the top are two coarse sand beds 15 feet apart containing a few specimens of *Ostrea* and *Littorina*, marine fossils (locality 4743)	400

	Feet.
Yellowish-gray earthy sand, sandy clay, and clay in well-defined massive beds, with some pebbly sand	650
Dark clay	75
Thick zone of pebbly sand	150
Chiefly dark clay	150
Yellowish-gray fine sand yielding whitish surface sand	75
Pebbly sand	70
Sandy clay	80
Chiefly fine gray sand, alternating with pebbly sand, sandy clay, and clay; a thick zone of pebbles and bowlders occurs about 350 feet below the top	1,100
Chiefly fine gypsiferous ashlike light-gray sand, with dark clay layers and many large pebbles scattered through, but no prominent gravel beds; lower portion is the fresh-water zone, but no fossils were here found; it overlies dark clay and *Mya* beds at the top of the Etchegoin	350
	3,100

The beds near the base of the Tulare are tilted as high as 40° and 45° in the south-central part of the hills on the southwest flank of the anticline, but toward the edge of the hills the dip gradually decreases. On the northeast flank of the anticline and in the northern and southern parts of the hills the dip is not as steep as this. Furthermore, the belt of exposed beds is not as wide elsewhere as in the part of the hills where the above sections were made and therefore no approach to the total thickness can be measured elsewhere. In the section in the northern part of the hills given in figure 5 the thickness is much less, the upper portion of the formation being presumably buried beneath the plain. Thence southward toward Avenal Gap the exposed section grows constantly thicker. This fact may be due in part to a thickening of the formation southward in the same manner as the Etchegoin thickens, but no proof of such a change can as yet be offered.

TULARE IN THE KREYENHAGEN AND JACALITOS HILLS.

The Tulare beds dip under the Kettleman Plain and reappear on the western arm of the syncline along the border of the Kreyenhagen and Jacalitos hills. As in the Kettleman Hills, the formation dips more steeply and exposes a much greater thickness toward the south, but here this difference is even more pronounced. The beds have a dip of only a few degrees northwest of Zapato Creek, and form a comparatively narrow belt to the point where they are overlapped by the alluvial deposits of Pleasant Valley. South of Canoas Creek they rise to extremely steep dips, appearing almost overturned in places, and cover a wide belt. They are, however, very poorly exposed. The formation here consists of deposits similar to those in the Kettleman Hills, but the basal fossiliferous beds have not been found. The formation is chiefly characterized by its heavy gravel deposits, which, contrary to the rule in the Kettleman Hills, in places rest

directly upon the Etchegoin, forming high hills fronting the valley. This occurrence of heavy bowlder deposits near the base has led to the theory that possibly the fresh-water basal zone is lacking and that a higher portion of the Tulare has overlapped upon the Etchegoin. North of Zapato Creek an unconformity between the Tulare and the Etchegoin is shown to exist by the fact that the gravel beds of the former overlap upon the Etchegoin and locally cover up some of the higher beds of that formation. Southeast of Big Tar Canyon the basal portion of the Tulare is sand and clay and is not strongly characterized. Its basal line is assumed to be at the top of a zone of white nodular shale beds interbedded with sand containing the strange bones mentioned before as occurring both in the Etchegoin and Tulare in the Kettleman Hills. This zone may be the equivalent of the white shale at the contact of the two formations in the northern part of the Kettleman Hills. The flinty nodules contained in this zone, which are similar in appearance to nodules and laminæ occurring at about if not exactly the same horizon elsewhere in the Kreyenhagen and Kettleman hills, are made up of 88 to 89 per cent of silica, according to an analysis by R. C. Wells, of the United States Geological Survey. They contain only a trace of lime. The Etchegoin and Tulare appear conformable in the southern part of the Kreyenhagen Hills. The latter formation has a thickness of at least 2,000 feet and probably much more.

TULARE IN THE GUIJARRAL HILLS.

In the northern part of the Coalinga district the Tulare is doubtless continuous beneath the valley floor but does not appear definitely exposed except in the Guijarral Hills, which are entirely covered by deposits of coarse gravel of this formation, the name of the hills being derived from this feature. The beds in these low hills are almost horizontal, but appear to dip slightly toward Pleasant Valley and Polvadero Gap, giving the surface the appearance of a plane inclined in those directions. The beds are exposed by the Coalinga anticline and probably belong in the lower middle portion of the formation. They may be traced northward on the east flank of Anticline Ridge, but are throughout this region poorly exposed. The contact with the underlying Etchegoin can not be definitely traced nor the relations of the two formations determined.

ORIGIN OF THE FORMATION.

The transition from salt to fresh water conditions that took place at the beginning of the Tulare period has been discussed, but it is uncertain what conditions prevailed during the subsequent period during which the great bulk of the formation was deposited. After the deposition of the fossiliferous fresh-water beds the process of

change continued further and culminated in a fairly constant set of conditions that were prevalent during the greater part of Tulare time. The change may have brought about a deepening of the body of fresh water, or a return of the sea over the same area in which this formation was laid down, or, most probable of all, the transition may have simply reached its natural conclusion in the establishment of land conditions.

Lithologically, the Tulare is somewhat similar to the marine Tertiary formations in which unconsolidated strata are common, but the absence of fossils, which are so abundant in those marine formations, makes it doubtful whether any great part of it is of marine origin. Its constituent materials show that it was formed at no great distance from their source and that, if marine, it must have been littoral. It is hardly supposable that near-shore marine or lacustrine deposition could have continued throughout the long period represented by this formation, either of marine or fresh-water character, without fossil remains being left, as they were in the case of the earlier formations and of the basal fresh-water zone. The presence of the marine fossils noted in the second section above proves that the sea gained access to the basin in which the formation was laid down for a short time, at least, in the later portion of the period. It is not improbable that similar temporary incursions of the sea occurred at other times.

The Tulare beds exhibit still greater resemblance to the more recent horizontally stratified deposits of stream wash, wind-blown dust and sand, etc., forming the surface of the floor of the Great Valley and the various small valleys along the border of the Diablo Range. These deposits consist of earthy clay, sand, gravel, and fragmentary matter and find their counterpart in the beds of the Tulare. On the basis of this analogy and the general absence of fossils in the main part of the Tulare, it may be assumed that a large part of the formation was subaerial in origin, being the accumulation in the basin between the Sierra Nevada and Diablo ranges of the material worn from them during a long period of time.

The Great Valley of California is structurally a geosynclinal trough that must have been undergoing a process of filling during much of Tertiary and Quaternary time. A large part of all the material washed from the eastern flanks of the Coast Ranges and the broad western face of the Sierra Nevada during this period must have found lodgment in it. During the late Tertiary and the Pleistocene the valley was probably similar to that of to-day and the deposits were forming in it as now. When the movements took place during the Pleistocene the valley deposits were uplifted in places along the border and exposed as the formation here described under the name Tulare. During the period since that time aggradation in the large and small valleys of this region has continued, and if the border of

the Great Valley and the filled synclinal basins along the present eastern side of the Diablo Range should now be subjected to uplift a thick subsequent formation resembling the Tulare would be brought to light. Such a formation would be in part made up of material derived from the Tulare and in some places would be decidedly unconformable, though in others perfectly conformable and continuous with it.

The occurrence of the mollusks and fish bones in such various associations and their final disappearance lend probability to the view that the later Etchegoin and early Tulare period was one of varying and possibly alternating estuarine, tide-marsh, and lake conditions, changing gradually to those of dry land. Such a change would be brought about by aggradation alone or by gradual uplift, whereas a theory of any other change would involve the assumption of complicated movements.

The body of fresh water occupying the area of the present Kettleman Hills at the beginning of Tulare time, as indicated by the fossils, must have been shallow and must have extended over an almost level surface. It may have been very much such a lake as the present Tulare Lake, in which mollusks similar to those that inhabited the Pliocene lake are now living. W. L. Watts[a] gives a list of fresh-water shells obtained from beds at McKittrick, in Kern County, about 40 miles south of the south end of the Kettleman Hills. If these represent the same horizon as the basal beds of the Tulare they prove a great extent for the lake of that period. The absence of fresh-water fossils higher in the formation in the Coalinga district proves that this shallow lake did not persist as such. It either deepened or vanished. If it deepened to such a depth as to preclude the existence of organisms such as would be preserved in the sediments at its bottom, it is strange that the deposits should have been so coarse, and it would be expected that fossils would be found somewhere along the belt that must have been nearer the shore, as for instance in the deposits that lap up over the Etchegoin west of the Kettleman Plain. And if such a great thickness of beds is considered as having been deposited in a deep lake it is necessary to postulate the existence of an unbroken barrier between it and the open ocean. The marine fossils noted in the second section above, in the upper part of the formation, represent an incursion of the sea that was probably brief. The beds above and below the zone of these fossils are similar and probably originated under the same conditions. If those below are supposed to be of deep-lake origin, it must be supposed, to be consistent, that the opposition to the entrance of the sea was temporarily overcome and then reestablished.

[a] Bull. California State Min. Bur. No. 3, 1894, p. 49.

The most natural conclusion regarding the Tulare period in the central valley is that it was for the most part one of land conditions somewhat similar to those prevailing to-day, and that the strata were formed subaerially as widespreading deposits of the streams descending the mountains on either side of the valley. There were probably various secondary transporting and sorting agencies, such as gravity, winds, floods, and temporary lakes.

Fairly constant subsidence probably went on, keeping the surface of the filling basin near the level of the sea, and at times allowing the sea to enter, as a result of a slight disturbance of the equilibrium maintained between aggradation and subsidence. There is no known reason for believing that at any time a structural barrier across the Great Valley determined a sharp line where land, lake, river, or tide-marsh conditions ended and sea began.

In the collection of Stanford University there are some marine fossils that were obtained at a depth of 1,058 feet in an artesian well at the east edge of Tulare Lake (in sec. 12, T. 22 S., R. 22 E.).[a] Among them are many good specimens of *Ostrea lurida* Carpenter, together with fragmentary shells, one a small shell resembling *Mactra* or *Venus* and another a piece of a coarse hinge resembling that of *Mulinia*. The matrix is medium-grained, clay-colored, fairly well cemented sand, containing subangular fragments of white siliceous shale. W. L. Watts[b] cites a well boring near Tulare Lake in which fresh-water fossils were found at a depth of 1,058 feet. It would appear to be the same instance, but his reference to the shells as fresh-water was probably not based on his own observation. F. L. Ransome[c] cites an instance at Stockton of fresh-water shells found at a depth of 600 feet. Such occurrences are more in keeping with the theory of occasional encroachment of salt water, and of local fresh-water deposits formed in marshes or in temporary shallow lakes, like the present lakes in the southern end of San Joaquin Valley, than with the theory of the long-continued occupation of the basin by the sea or by a large, deep lake. It is not known whether the wells cited had reached the Tulare formation at these depths, for where the deposits forming the valley floor are undisturbed it would be impossible to distinguish between the beds limited by the arbitrary boundaries of the Tulare and the later sediments into which they must grade. But the question of origin is believed to be the same for the Tulare as for the subsequent deposits.

According to the theory of the origin of the Tulare above outlined the formation would grade seaward into an equivalent with more and more abundant estuarine elements and finally into a littoral

[a] They were sent in 1892 by Mr. Harvey G. Anderson through Mr. S. A. Blythe, and have been obtained for examination through the kindness of Prof. J. Perrin Smith.

[b] Bull. California State Min. Bur. No. 3, 1894, p. 20.

[c] Bull. Dept. Geology Univ. California, vol. 1, 1896, p. 381.

marine formation. It is believed that the latter is represented in the Merced formation on San Francisco Peninsula.

FOSSILS AND AGE.

FOSSILS.

The only important fossiliferous zone in the Tulare is that at the base, which may be called the *Anodonta* zone, because of the abundance in it of fresh-water mussels of this genus. The following species have been found in the Tulare formation in the Coalinga district:

Tulare (Pliocene-lower Pleistocene) fossils from the Coalinga district.

Name.	4715.	4721.	4731.	4732.	4735.	4737.	4738.	4739.	4740.	4743.
PELECYPODA.										
Anodonta kettlemanensis Arnold		×	×	×	×	×				
Gonidea coalingensis Arnold and var. cooperi Arnold		×	×					×		
Ostrea lurida Carpenter										×
Sphærium cooperi Arnold			×	×						
Sphærium kettlemanensis Arnold			×	×						
GASTEROPODA.										
Amnicola andersoni Arnold				×						
Amnicola sp	×									
Carinifex marshalli Arnold				×						
Goniobasis kettlemanensis Arnold	×				×					
Goniobasis nigrina? Lea				×						
Littorina cf. mariana Arnold										×
Physa humerosa Gould				×						
Physa wattsi Arnold				×						
Planorbis vanvlecki Arnold	×		×	×						
PISCES.										
Fish, bulbous growths			×				×	×	×	
Fish spines										

4715. South end of Kettleman Hills, sec. 10, T. 25 S., R. 19 E. The marine and fresh-water fossils at this locality are more or less mixed owing to their scattered occurrence over the surface of the eroded upturned beds.

4721. Northeast border of Kettleman Hills, 4 miles west of Tulare Lake, on summit of 758-foot hill, NE. ¼ sec. 15, T. 22 S., R. 18 E. Fresh-water zone at base of Tulare.

4731. Northeast border of Kettleman Hills, near northwest end, on top of hill (elevation 905 feet) just east of old road and cabin, NW. ¼ NE. ¼ sec. 35, T. 21 S., R. 17 E. Fresh-water zone just above oyster bed of locality 4728.

4732. About 2 miles from northwest end of Kettleman Hills, on south side of main ridge, 1½ miles northwest of 1,245-foot hill, SW. ¼ NE. ¼ sec. 30, T. 21 S., R. 17 E. Fresh-water zone at base of Tulare.

4735. Central part of Kettleman Hills, on southwest side, 1 mile southwest of 1,370-foot hill and one-third mile northwest of oil derrick, in center of south line of SW. ¼ sec. 19, T. 22 S., R. 18 E. Fresh-water zone at base of Tulare.

4737. East side of Kettleman Hills, east of Dudley-Lemoore road, NE. ¼ SW. ¼ sec. 17, T. 23 S., R. 19 E. Fresh-water zone overlying upper Etchegoin bed of locality 4736.

4738. In Kreyenhagen Hills, 20 miles southeast of Coalinga, one-fourth mile east of B. M. 872 feet just south of El Cerrito well, SE. ¼ NW. ¼ sec. 14, T. 23 S., R. 17 E. In white shale zone at base of Tulare, as mapped.

4739. Same general locality as 4738, on point of 900-foot hill, nearly 1 mile northwest of B. M. 872 feet, SE. ¼ sec. 10, T. 23 S., R. 17 E. At contact of Etchegoin and Tulare.

4740. Near northwest end of Kettleman Hills, 2 miles north-northwest of 1,245-foot hill, east of center of SW. ¼ sec. 20, T. 21 S., R. 17 E. Fresh-water zone just above Etchegoin oyster beds and white shale of locality 4716.

4743. On west side of Kettleman Hills, along Dudley-Lemoore road, in steeply dipping beds of pebbly sand exposed in bed of arroyo, 1,000 feet up gully from edge of plain, in north part of SW. ¼ sec. 35, T. 23 S., R. 18 E. About 2,500 feet above fresh-water zone at base of formation.

FAUNAL RELATIONS AND AGE.

A comparison of the above list with the lists of species from the same locality prepared by J. G. Cooper[a] shows a marked discrepancy between the two. This is caused by the different identifications of

[a] Proc. California Acad. Sci., 2d ser., vol. 4, May 26, 1894, p. 167; Bull. California State Min. Bur. No. 3, 1894, p. 55; Proc. California Acad. Sci., 3d ser., Geology, vol. 2, 1905, p. 180.

Doctor Cooper and the senior author of this report. Cooper identified the Kettleman Hill species, with the exception of two forms, as species now living, while Arnold, after a careful comparison of the fossils with the series of recent fresh-water mollusks in the United States National Museum, decided that with three exceptions the fossils were new, although in most cases allied to recent forms. A comparison of the two lists discloses the following relations:

Cooper's identification.	*Arnold's identification.*
Anodonta decurtata Conrad	Anodonta kettlemanensis Arnold.
Anodonta nuttalliana Lea	Probably same as above.
Amnicola turbiniformis Tryon	Amnicola andersoni Arnold.
Carinifex newberryi Lea	Carinifex marshalli Arnold.
Goniobasis occata Hinds	Goniobasis kettlemanensis Arnold.
	Goniobasis nigrina (?) Lea.
Margaritana subangulata Cooper	Gonidea coalingensis Arnold.
	Gonidea coalingensis var. cooperi Arnold.
Physa costata Newcomb	Physa wattsi Arnold.
	Physa humerosa Gould.
Planorbis tumens Carpenter	Planorbis vanvlecki Arnold.
Sphærium dentatum Haldeman	Sphærium cooperi Arnold.
	Sphærium kettlemanensis Arnold.

This fauna indicates that the basal Tulare in the Coalinga district is possibly older than the lowest known fossiliferous beds in the Santa Clara formation of the Santa Cruz region and certainly very much older than the fresh-water fossils from the Colorado Desert of southern California. In fact, the basal Tulare is believed to be the fresh-water equivalent of the San Diego formation and lower Pliocene in age. About 2,500 feet above the base of the Tulare *Ostrea lurida* Carpenter, a species so far known only from Pleistocene and Recent faunas, has been found. This fact is interpreted as indicating a recurrence of marine or estuarine conditions during late Tulare time and the extension of the formation into the Pleistocene.

IMPORTANCE WITH RELATION TO PETROLEUM.

The Tulare formation does not come into contact with the oil-bearing formations and contains no traces of oil. Over most of the area in which it occurs it is separated by so great a thickness of deposits from the productive zones that its mere presence is usually sufficient to indicate the inaccessibility of the oil.

TERRACE DEPOSITS AND ALLUVIUM (QUATERNARY).

CHARACTER AND EXTENT.

The later Pleistocene and Recent periods are represented by a mantle of alluvium and terrace deposits covering the floor of the Great Valley and the large side valleys, extending over the bottoms of the smaller valleys and over the lower slopes of the foot-

hills. The larger areas of these deposits are shown on the map (Pl. I), but the minor ones where the deposits form only a thin film over the earlier formations have not been shown. In fact, they would be very difficult to distinguish in many places. In the large valleys it is probable that these deposits have a thickness of several hundred feet at least, as the late period has been largely one of aggradation over these basins. Elsewhere the deposits are merely superficial and the smaller valleys and canyons are characterized rather by the absence than by the presence of recent fillings. The smaller valleys show evidences of several terraces along their sides, some of these being much better preserved than others. Along portions of Zapato Creek, as shown in Plate IV, *A*, six or seven terraces may be counted, including one at the summit of the foothills that is of widespread importance. These terraces are frequently covered with stream gravel and sand, and such materials are widely scattered over the lower portions of the foothill belt, their presence tending to confuse the geology where it is not determinable whether they are of fluviatile origin or are derived from weathering of the underlying rocks. The greater portion of the whole region under discussion is covered by surface soil and residual sand derived from the soft formations. All of these comparatively recent deposits are similar in materials and appearance to the underlying formations and are not easily distinguishable from them. They have the effect of obscuring the main facts of the geology over large areas.

A small sand ridge, appearing to be the relic of an old beach line of Tulare Lake, has already been mentioned under the subject of topography. It owes its present position in part to the decrease in area and depth of the lake and in part to the relative uplift of the area of the Kettleman Hills.

VALLEY ALLUVIUM.

The nature of the deposits covering the valley floors has been referred to in connection with the Tulare formation, to which they are similar. The exposures of these deposits afforded by the shallow channels of the streams flowing across the plain are limited to the uppermost layers, but it is probable that these give a fair representation of the character of all of the post-Tulare beds. A typical exposure is pictured in Plate XII, *A*. A feature of the Quaternary deposits is that they are not predominantly coarse, but on the contrary are composed largely of fairly even grained sand and clay, often of an earthy appearance, horizontally stratified in intergrading zones rather than beds. Lenses of gravel and gravelly sand are intercalated. Even near the hills in the gradually sloping alluvial fans the deposits are largely of fine materials, being in great part derived from soft formations. But masses of coarse débris containing bowlders, fragments, and concretions from the older formations are also common.

LOOSE SOIL.

The soft surface sand and clay, whether originating through residual weathering or brought from a distance, or even where in place as a part of the underlying formation, is characteristically porous and crumbly. It is in many places and over large areas so soft that a horse can not step on it without sinking in over his hoofs or considerably deeper. This looseness of the soil is due to the complete desiccation to which it is subjected during most of the year. In the Kettleman Hills and Plain the difficulties of travel due to this cause are aggravated by the myriads of rodent burrows with which the surface is riddled. The ground caves in under a horse every little way.

STREAM CONGLOMERATE ON WHITE CREEK.[a]

During late Quaternary time deposits of hard conglomerate have been in process of formation along the bed of White Creek and are still being formed. The creek flows from an area of serpentine and other metamorphic rocks and carries much mineral matter, which it deposits as the water evaporates, forming a white coating on the gravel of the stream bed and cementing it into a solid pavement. Through the pavement thus formed in a previous period the stream has carved a channel, leaving the conglomerate as a terrace deposit along the sides of the valley. The gravel is made up of pebbles and bowlders of many kinds of metamorphic and sedimentary rocks, but the cementing material is so hard that the stream in cutting the conglomerate forms clean cross sections through all the constituent materials.

At least three terraces appear along the sides of the valley of White Creek. It is on the middle one of these terraces, which is usually 20 to 40 feet above the stream, and on the lower one, which forms the present valley floor and stream pavement and which is in most places a few feet above the channel of the stream, that the conglomerate occurs. The conglomerate extends for about 5 miles along White Creek, beginning at a point some 2 miles below the edge of the serpentine area and terminating about a mile above the confluence of White Creek with Los Gatos Creek. The ledge forming the terrace capping or stream-bed pavement is in places 15 feet or more thick. The Cretaceous sandstone which underlies the capping is less indurated than the conglomerate and gives way more readily to weathering and erosion. As a result, the capping is undercut and large blocks of it break off. Thus erosion removes the deposit more rapidly than it would a formation of such hardness laid upon a more resistant foundation.

[a] This subject was more fully treated in a paper by the present writers entitled "Conglomerate formed by a mineral-laden stream in California" (Bull. Geol. Soc. America, vol. 19, 1908, pp. 147–154).

An analysis by Dr. E. C. Sullivan shows that the cement deposited on White Creek is made up principally of calcium and magnesium carbonates, with minor amounts of silica and ferric oxide. There is little doubt that the source of this cement is in the area of serpentine and associated metamorphic rocks on Joaquin Ridge. Magnesium carbonate and silica are only slightly soluble in water under surface conditions, so that when once deposited with the associated minerals as a hard cementing matrix between the pebbles and bowlders along the stream bed the resulting conglomerate is necessarily very resistant to erosion and permits cutting of the constituent bowlders rather than removal of these rocks from the matrix when attacked by running water.

IGNEOUS ROCKS.

The only igneous rocks occurring within the Coalinga district are associated with the Franciscan formation. The Cretaceous, Tertiary, and Quaternary formations were not affected by igneous intrusions, and there is no evidence that there was volcanic activity in this or the adjacent regions during these periods.

SERPENTINE.

The serpentine that has already been described in connection with the Franciscan as covering such a wide region in the heart of the Diablo Range originated as an intrusion of basic igneous rock into the sedimentary Franciscan formation before the beginning of the period in which the Knoxville-Chico beds were laid down. There are many different varieties of the rock, varying from hard, little-altered dark-green and bronze-green peridotite, in which the constituent crystals are well displayed, to much metamorphosed and surficially altered serpentine, soft, smooth, green, white, and variously colored, and to related minerals. The varieties resemble those that are associated with the Franciscan formation throughout the Coast Ranges.

The hard streaks of rock form irregular outcrops and the softer portions weather over large areas into bare, soft heaps of comminuted serpentine in the shape of dust, sand, flakes, and nodules of many colors. The material has gathered much more rapidly than erosion could carry it away, and covers up the rocks to a depth of several feet in places. The streams flowing from the serpentine area, notably White Creek, carry much of the serpentine powder, and deposit it as a dustlike coating on the rocks along their course. It is made up chiefly of small flakes of an olive-gray color and resembles bran in texture and consistency. Outcrops and weathering deposits of similar character were the source of the serpentinous shale of the Big Blue, described with the Santa Margarita (?) formation (middle Miocene).

SODA SYENITE FROM WHITE CREEK.

Toward the head of White Creek is a hill formed of a hard hornblende-bearing igneous rock that seems to have been formed as a boss intrusive in the serpentine. It is a beautiful soda-bearing syenite, mottled black and white and varying from an extremely fine grained facies to a porphyritic one, in which there are large, perfect needles and lath-shaped crystals of hornblende. The area of this rock as shown on the map is slightly exaggerated.

Several somewhat weathered specimens of this syenite showing variations in coarseness from the fine to the porphyritic texture were secured. One of these specimens was chemically analyzed by Dr. W. F. Hillebrand, of the United States Geological Survey, and they have been microscopically examined by Mr. E. S. Larsen, jr., of the Survey, who has kindly furnished the following description.

The specimens are all granitoid rocks of light-gray color composed chiefly of dull white feldspar and its decomposition products, but with numerous long prisms of a black lustrous hornblende. In addition, most specimens show secondary calcite, analcite, and green ægirite. Drusy cavities are common containing crystals of feldspar, prisms of hornblende, and secondary ægirite, calcite, zeolite, and analcite. One specimen of the rock shows both the fine and the coarse-grained types, separated by a sharp but irregular boundary.

A microscopic study shows that the specimens are very similar and that they are made up largely of plagioclase with considerable brown hornblende, a little biotite, accessory apatite, zircon, and black iron ore, and secondary calcite, analcite, ægirite, and white mica. No nephelite or orthoclase were found, though a few very fine intergrowths that were observed were thought to be possibly orthoclase and albite. The texture is granulitic. The feldspars generally show very fine, irregular albite twin lamellæ which give a maximum extinction angle of 16°; the index of refraction is less than 1.540, and the extinction angle measured on cleavage pieces after 010 is 18° and after 001 is 5°. They are therefore albite. In one of the specimens there are numerous feldspar phenocrysts which show a core of andesine or andesine-labradorite grading into a broad band of albite. Alteration is always well advanced and gives rise to natrolite and white mica.

The hornblende occurs in long, well-developed prisms without terminal planes. It is often twinned. Pleochroism is very marked in dark brown and yellow, the birefringence is moderate, and the extinction angle ($Z \wedge c$) is 14°. It is probably barkevikite. Many of the ends and borders are altered to a very dark greenish blue amphibole, but otherwise they are very fresh even where the associated feldspar is completely decomposed.

Ægirite is rather abundant in rough prisms or dendritic growths, which are usually collected in patches. It is strongly pleochroic in greens and yellows, is highly birefracting, and has X parallel to the length of the prisms. Analcite is not common in the fresher rock, but in one specimen it has almost completely replaced the feldspar. Megascopically the latter specimen is not very different from the fresher rock, but the thin section consists mainly of isotropic analcite with scattered grains of calcite, zeolite, ægirite, and white mica, all inclosing fresh crystals of barkevikite. In places a few feldspar crystals can be seen, but they are almost completely altered to natrolite, white mica, etc.

The following analysis was made by Dr. W. F. Hillebrand. The rock was of the fine-grained type and was fairly fresh. It consisted of albite, hornblende, some biotite, accessory apatite, zircon, and iron ore, and secondary ægirite, calcite, zeolite, analcite, and white mica. The analysis was made on powder of 100-mesh size and hence the results for H_2O and FeO are probably very nearly right.

Analysis of soda syenite from the head of White Creek.

[By W. F. Hillebrand.]

SiO_2	60.00	MgO	1.40
TiO_2	.42	K_2O	.94
ZrO_2	.03	Na_2O	9.31
Al_2O_3	16.88	Li_2O	Tr.
Cr_2O_3	None.	H_2O-	.43
Fe_2O_3	1.83	H_2O+	1.53
FeO	3.02	P_2O_5	.14
MnO	.12	CO_2	.59
CaO	3.16	S	Tr.
SrO	.02		
BaO	.06		99.88

The norm computed from this analysis according to the method of the quantitative classification follows:

Norm computed for soda syenite from the head of White Creek.

Orthoclase	5.56	Diopside	11.04
Albite	69.04	Olivine	1.28
Anorthite	1.67	H_2O	1.96
Nephelite	5.40	CO_2	.59
Ilmenite	.76		
Apatite	.34		100.19
Magnetite	2.55		

This places the rock in Class II, order 5, rang 1, subrang 5. It appears to be the first rock of this division to be described. It closely resembles the umptekite described by W. Ramsey.

To sum up, the rock has a granulitic texture and consists, when fresh, of albite and barkevikite with a little biotite, accessory zircon,

apatite, and iron ore. Alteration of the feldspar has produced zeolites, white mica, calcite, analcite, and ægirite. The chemical analysis is noteworthy on account of the high soda and low potash. The orthoclase and nephelite indicated by the analysis are probably not present.

STRUCTURE.

Some of the broad features of the structure of the Coalinga district have been briefly touched on in the preceding discussions of the topography and geology, and these as well as many of the minor features will be further treated in connection with the occurrence of petroleum in the description of the developed territory. The structural axes and the general attitude and succession of the strata are represented on the maps (Pls. I, XV, and XXII) and in the various profile sections (figs. 6, 7, 8; Pls. XVI, XIX, XX, XXI), and therefore merely a general review of the structural phenomena and the discussion of certain particular points are necessary here.

CROSS STRUCTURES AND THEIR TOPOGRAPHIC INFLUENCE.

The structure of the Diablo Range is, broadly speaking, anticlinal, and its eastern flank is composed of a great monocline of sedimentary strata dipping toward the San Joaquin Valley. But the regularity of this monocline is broken by a series of waves and offsets into which it was thrown by various important as well as minor plunging anticlinal and synclinal folds, and by faults that run in various directions both parallel with and oblique to the main structural trend of the mountains. This main trend parallels the general course of the Sierra Nevada, the Coast Range, and the coast in this portion of California, and is approximately N. 35° to 40° W. The general orientation of the secondary structural axes is considerably more to the west of north than this. These show their influence prominently in the topography by producing the oblique spurs and valleys discussed under the subject of topography. The same features, both topographic and structural, may be observed south of the Coalinga district and also in the mountainous tracts west of it. It is owing to such structures that the Gabilan Range converges with and joins the Diablo Range in the latitude of the Coalinga district; and the various discontinuous spurs of the high and complex portion of the Diablo Range, which are arranged in positions en échelon with one another, may be explained on the same basis. It would appear therefore that the region has been subjected to two main sets of compressional forces, the one set acting on a line running roughly N. 50° E. (and S. 50° W.), and the other set along a line running N. 20° to 30° E., making a counter-clockwise angle of about 20° to 30° with the former set.

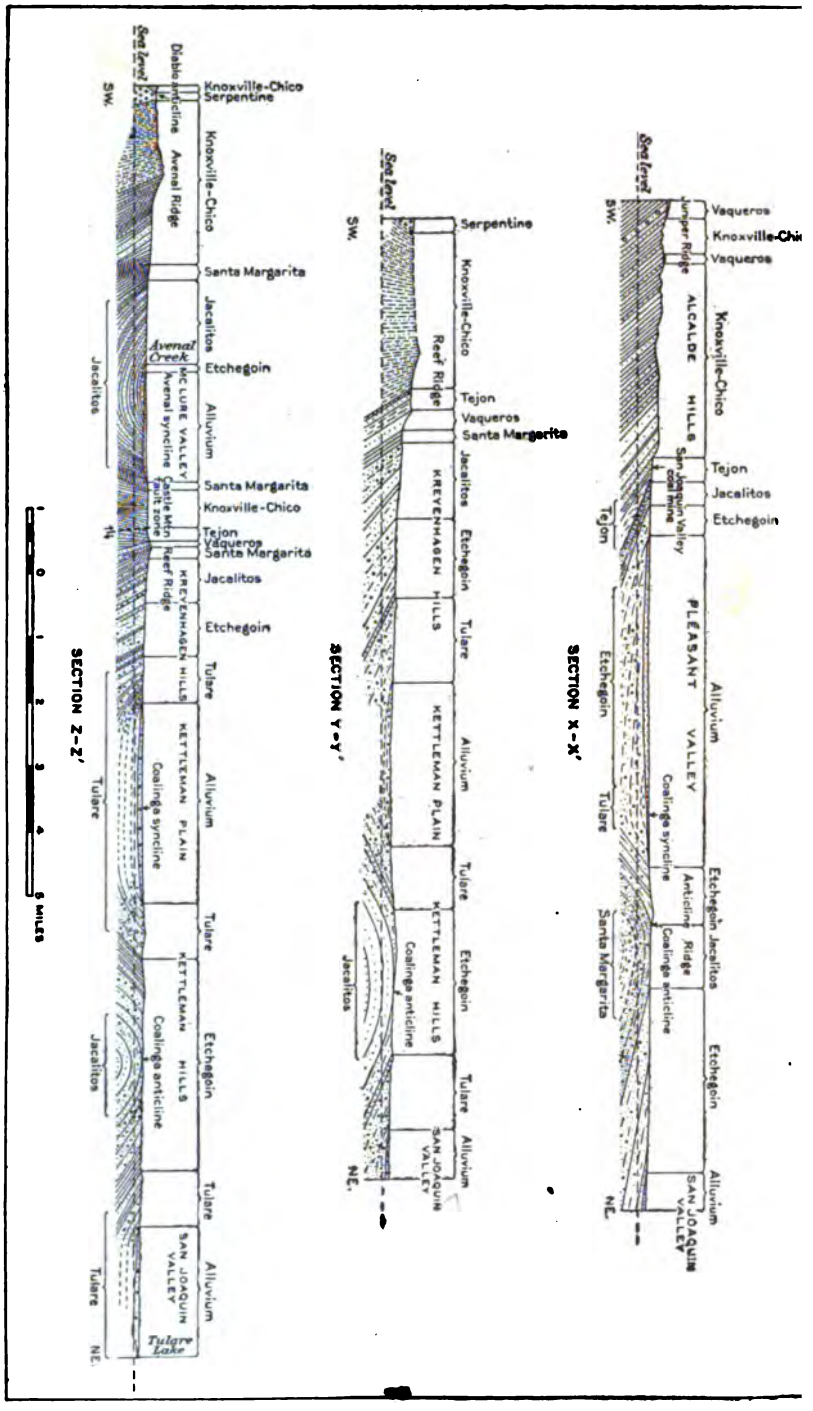


FIGURE 6.—Geologic sections across Coalinga district. (See Pl. I.)

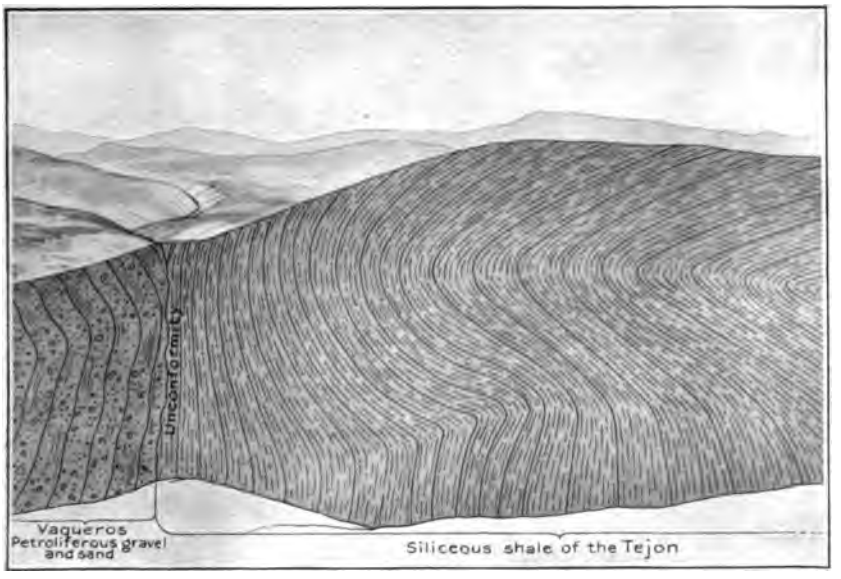
PERIODS OF MOVEMENT AND THE EFFECTS ON FORMATIONS OF DIFFERENT AGE.

A large part if not the major part of the movement that has resulted in the disturbance of the Tertiary beds in this region, and possibly of the Cretaceous beds over considerable areas in which they were not previously greatly disturbed, took place in Pleistocene time after the deposition of the Tulare (Pliocene-Pleistocene) formation. This is indicated by the fact that the later Tertiary and early Pleistocene formations have been disturbed almost as much as the older ones, and in some places as much as or even more than the Cretaceous beds. An example of this is found in the beds exposed in the Coalinga anticline, where the Cretaceous strata dip gently and appear to have been folded hardly at all before the Eocene and Miocene beds were tilted on the same anticline to the vertical position. One reason, however, for this comparatively little disturbed condition of the Cretaceous formations is their compactness and relative homogeneity, by which they resist stresses that would severely disturb the later, more loosely consolidated beds. Relative immunity from disturbing forces is characteristic of the Cretaceous formations in many parts of California. But in most parts of the Coalinga district the Cretaceous strata have been closely folded in spite of their resistance and intricately faulted partly as a result of it, showing that the disturbances that brought about these results were very severe. These disturbances are thought to have occurred for the most part before the Tertiary, or at least before the Miocene, for reasons stated in the discussion of the geologic history. It is certain that important movements took place during Cretaceous and Tertiary time, notably at the close of the Tejon (Eocene) period of deposition, when the beds of that age were uplifted and greatly disturbed before the subsidence that allowed the deposition of the Vaqueros (lower Miocene) sandstone on their eroded surface, and also at the close of the Vaqueros period. As regards the still later movements, the facts that all the formations from the Cretaceous to the lower Pleistocene are in places approximately conformable in dip, and that at least the Miocene, the Pliocene, and the later portion of the series almost invariably appear so, indicate that the whole series was affected as one during the Pleistocene epoch by extraordinarily severe disturbances.

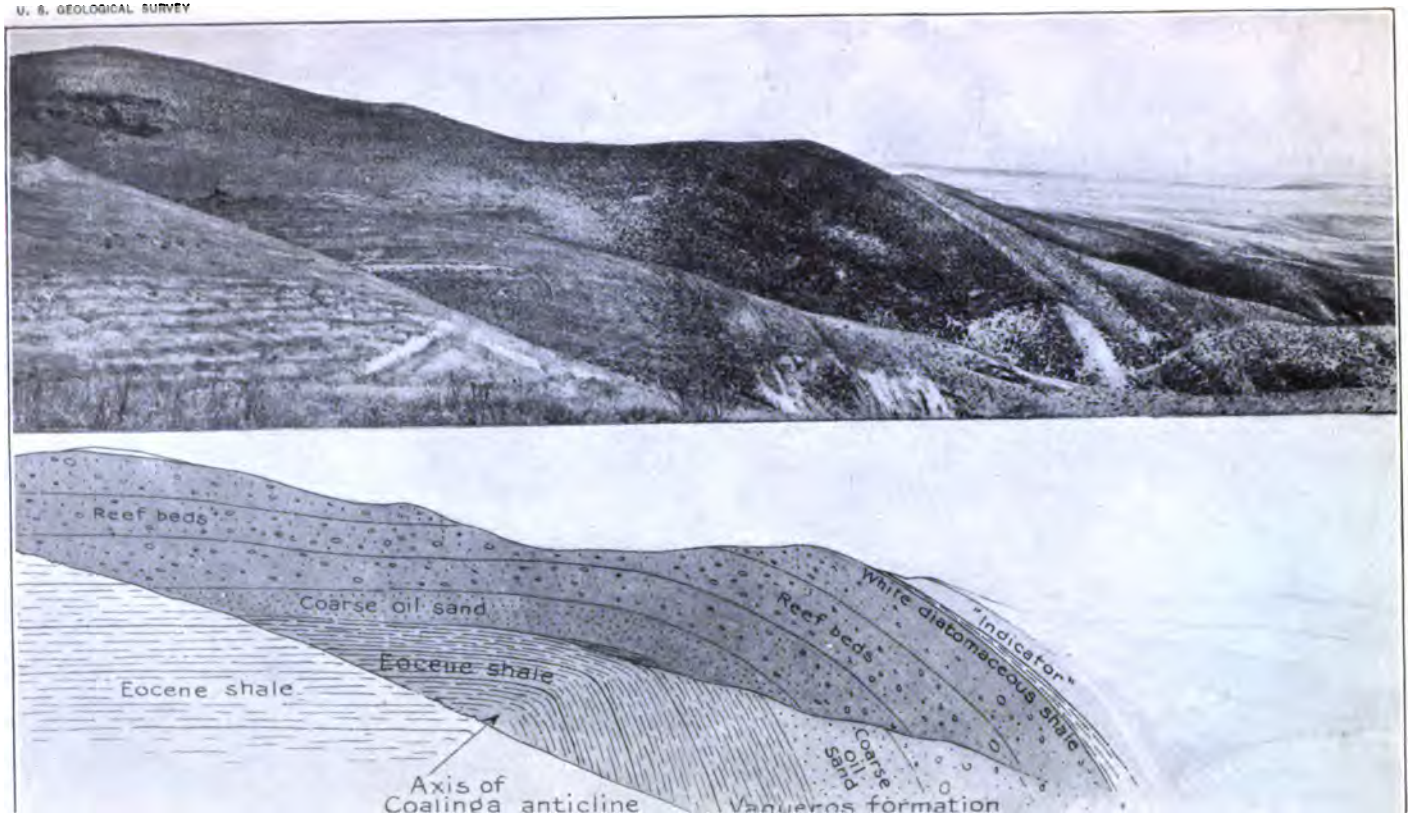
In the Tertiary formations the land movements have resulted chiefly in folding rather than in faulting. The strata of these formations are everywhere tilted, at angles ranging from a few degrees to the vertical, and are locally overturned, but evidences of faulting are by no means as common. The only fault of importance that is definitely known to affect the Tertiary formations in this district is one shown on the maps (Pls. I and XV) in the Alcalde Hills southwest of

A. OVERTURNED SHALES OF TEJON FORMATION IN AXIS OF COALINGA ANTICLINE.

Looking northwest across foothills 8 miles north of Coalinga. Note base of overlying Vaqueros on left; the vegetation following lines of bedding in the fold; Jnaquin Ridge in the distance. Taken from Tejon-Vaqueros contact on ridge shown in Plate VII. Photograph by Ralph Arnold.



B. DIAGRAM OF PLATE XIII, *A*.


Reef beds
Coarse oil sand
Eocene shale
Eocene shale
Axis of
Coalinga anticline
Reef beds
White diatomaceous shale
"Indicator"
Coarse oil sand
Vaqueros formation

Coalinga. This fault has a downthrow of at least 200 feet on the northeast. It is discussed in the description of the geology of the Westside field (p. 222). A few small local faults, such as are shown in Plates VI, *B*, and X, have been noted. The displacement shown on the left in Plate X is due to collapse of the soft beds of the Big Blue, which is mapped with the Santa Margarita (?) formation (middle Miocene).

The older formations, on the other hand, are much faulted as well as folded, and many faults in them have not been mapped. The Knoxville-Chico (Cretaceous) beds exposed along Los Gatos Creek afford an excellent example of the great number of large and small faults that occur along a fault zone such as that which determines the position of this old valley.

THICKNESS OF THE SEDIMENTARY STRATA.

The great thickness of the sedimentary strata along the flank of the Diablo Range is proof of the greatness and comparative continuity of the movements to which the land has been subjected during the recorded geologic history. The total maximum thickness of the different formations, as given in the columnar section (fig. 2), is not measurable in any one locality, but the total is found in many sections to be as much as 12,000 to 15,000 feet or more.

Possibly a slight exaggeration of thickness may result from the spreading of the beds at the surface, where they are relieved from pressure, and from the related tendency on the part of tilted strata to assume steeper dips at the surface than the true dip at depths. The steeply dipping and locally almost overturned beds of loose, dry sand, gravel, and clay toward the south end of the Kreyenhagen Hills suggest the probability of their having expanded at the surface and thus augmented their apparent thickness. Superficial spreading, uptilting, and disturbance occur likewise in the more compact older rocks, especially in the shales of the Knoxville-Chico (Cretaceous), Tejon (Eocene), and Santa Margarita (?) (upper middle Miocene). The tendency toward steepening of the dip at the surface is aided by gravitational movement of the soil. A local overturn at the surface in the shales of the Santa Margarita (?) formation is shown in Plate XI, *B*. The exaggeration of thickness due to such surficial phenomena, however, is hardly appreciable in some portions of the district, as, for instance, in the developed oil field, where the thicknesses of formations as revealed in the oil wells agree closely with those measured on the surface; and it is not thought that it results anywhere in a large proportional increase over the true thickness. The measurements of formations given in this paper are intended to represent fairly the thicknesses apparent in the surface outcrops, except in the discussion

of the developed territory, in which many figures are given that are based on the measurements obtained in wells.

It has been pointed out in the description of the formations how they vary in thickness within short distances. This variation is characteristic of the region. In the post-Eocene formations it may be partly explained by the theory that the gradual subsidence which took place during the different periods progressed more rapidly toward the south than it did in the northern part of the Coalinga district, where the shore line must have been near, and that the periods of land conditions interrupting the progress of sedimentation were more prolonged in the northern region. A large part of the irregularity of thickness is doubtless due to the removal of portions during intervals of erosion. Furthermore, much irregularity is due to the local variations in the nature of the deposits and to the original manner and amount of their deposition.

UNCONFORMITIES.

The number of unconformities between formations in the Coalinga district gives further proof that the region underwent almost continuous movements, and that these were of various kinds. The unconformities are rarely clearly apparent at the contacts between the formations, and the unconformable relations are usually to be made out only from a detailed study of (1) the areal distribution of the formations, which gives a clue to the presence of overlap, and of (2) the fossils, which indicate time breaks. The evident angular unconformities that have been discovered are between the Vaqueros (lower Miocene) and Tejon (Eocene) at various localities north of Coalinga; between the Tejon and older Cretaceous shales at points on Reef Ridge; between the Vaqueros and Cretaceous in the Alcalde Hills and on Juniper Ridge; between the Santa Margarita (?) (upper middle Miocene) and Vaqueros where the Castle Mountain fault zone crosses Reef Ridge; between the Santa Margarita (?) and Tejon at the same point and also at the San Joaquin Valley coal mine; and between the Santa Margarita (?) and Cretaceous along the north and east sides of McLure Valley.

The unconformity between the Tulare (Pliocene-Pleistocene) and Etchegoin (upper Pliocene) north of Zapato Creek is less definitely to be made out. Elsewhere the formations, even those profoundly distinct in age, generally appear conformable in dip, and it is not improbable that overlaps and unconformities that have not been made out occur within the formations that are treated in this report as stratigraphic units. That little reliance is to be placed on an appearance of angular conformity is made clear at several points north of Coalinga, where an appearance of such a relation between the Tejon (Eocene) and Vaqueros (lower Miocene) is to be found only

a short distance from points where the contact displays pronounced discordance in dip. Overlaps of all the Tertiary formations, except the Tulare, upon the Knoxville-Chico (Cretaceous) occur within the Coalinga district, thus proving their mutual unconformity. Except the overlap of the Etchegoin on White Creek, and that of the Vaqueros in the Alcalde Hills, over the sandstone of the Chico (Upper Cretaceous) these overlaps take place over the lower portion of the Knoxville-Chico. The variation of the formations in original areal extent and in thickness, lithologic character, and structure within small areas gives an indication of the local activity of the disturbing forces which have continued to act within this region.

MAIN LINES OF STRUCTURE.

Coalinga anticline and syncline.—Among the individual features of the structure in the Coalinga district the Coalinga anticline is next in importance to the general monocline on the eastern face of the Diablo Range. This anticline is one of the principal oblique structures of the range. It forms Joaquin Ridge and plunges toward the valley, exposing in turn the Franciscan rocks at the head of Joaquin Ridge and all the subsequent formations. The synclinal axis of its plunge is at Polvadero Gap, beyond which it is undoubtedly continued by the anticline plunging in the opposite direction, which causes the beds to dome up into the Kettleman Hills. At the south end of these hills, about a mile south of the mapped area, the anticline does not plunge beneath the surface of the valley again, as might be expected by analogy. On the contrary, it exposes a fairly low portion of the Etchegoin formation, beds several thousand feet stratigraphically lower than those exposed at the north end, and the hills are left incomplete, their termination being due to erosion rather than to structure as at the north end. The Lost Hills, which are within 10 miles south of the area shown on the map, are due to a continuation of the Coalinga anticline. The length of this fold within the district is 60 miles. Its principal features are its alternating plunges in different directions, its curving course indicating a complexity in the forces which have acted upon it, its asymmetry, and its broad summit and steep flanks. The plunges and arches of the anticline are indicated by symbols on the geologic map (Pl. I). The steep dips on its southwestern flank north of Coalinga as compared with the gently dipping summit and northeastern flank are very pronounced, these features being illustrated in Plates III, XIV, and XVIII and on the map of the Coalinga field (Pl. XV). Similar asymmetry is observable in the northern part of the Kettleman Hills, although the divergence in dip on the two flanks is not so great, the usual maximum dip being 35° to 45° on the southwest and 25° to 31° on the northeast. The Coalinga syncline is the parallel supple-

mentary feature and forms the topographic depression of Pleasant Valley and Kettleman Plain. Like the anticline, it plunges southwestward from Joaquin Ridge and rises again opposite the Kettleman Hills. West of Oil City it dies out in low dips on the flank of the anticline.

The folds and faults forming the other main spurs of the Diablo Range in this district have already been mentioned in the discussion of the topography.

Structure in the basin of Los Gatos and White creeks.—The structure in the basin of Los Gatos and White creeks between Joaquin and Juniper ridges is peculiar and complicated. A broadly folded anticline of Cretaceous beds with a locally sharp axis plunges southwest and northeast off the flanks of these two ridges toward the lower part of Los Gatos Creek, where it is crossed by a broad syncline plunging both northwestward into the axis of the White Creek basin and southeastward into Pleasant Valley. The syncline becomes sharply defined and regular along White Creek, where it incloses a remnant of Etchegoin (upper Miocene). Toward Pleasant Valley it broadens out to form part of the general monocline dipping toward the axis of the Coalinga syncline. A complicated set of faults occurs along Los Gatos Creek, as illustrated on the map (Pl. I). On the south side of the main line shown as the Los Gatos Creek fault zone the rocks are the thinly bedded dark shale and sandstone of the middle division of the Knoxville-Chico (Cretaceous). On the north side the massive sandstone beds of the upper division are faulted down into contact with them. The movement has been in the nature of a flattening out of the axis of the White Creek syncline toward its head, resulting in the formation of the main fault and of branch faults on the downthrow side, with greater and greater throw in the successive blocks toward the southeast. A great number of small faults are not of sufficient size to show on the map. Many of these may be seen in the exposures along the sides of Los Gatos Creek. Faulting of a somewhat similar character to that described has taken place likewise on the northeast arm of the syncline, but time did not allow a detailed study of the system. The basin of Los Gatos and White creeks has probably been an axis of movement along which successive disturbances have taken place during a long period. The southeastward continuation of this same line of disturbance probably accounts for the depression of the Coalinga anticline in the region of Polvadero Gap.

Zone of Alcalde Canyon.—Another old zone of movement is represented by the southeast face of Curry Mountain and the lower part of Alcalde Canyon from Alcalde toward Pleasant Valley. Profound faulting probably took place along the zone at different times. The sharp northern face of the 1,900-foot hill southeast of Alcalde suggests faulting, but no evidence of displacement in the later Tertiary forma-

tions has been obtained. The region north of Waltham Creek has had in some respects a different history from that to the south, and it is difficult to correlate the features of the geology in the regions so separated. To the south the formations have a far greater thickness, the sandstone portion or upper division of the Knoxville-Chico (Cretaceous) is lacking, the siliceous shales of the Santa Margarita (?) formation (upper middle Miocene) appear and gradually thicken and are only doubtfully to be correlated with the Santa Margarita (?) formation to the north, and a great thickness of the Tulare (Pliocene-Pleistocene) formation is steeply tilted and well exposed.

Structure in the Jacalitos Hills.—Between Alcalde and Reef Ridge there is a depressed area occupied by comparatively low rolling hills that represents the structural continuation of the old synclinal basin of Waltham Valley. The syncline of that valley plunges toward the southeast and ends just within the area shown on the map on the general monocline dipping away from Reef Ridge. This monocline is regular except for some low, broad plunging folds northwest of Zapato Creek. A noteworthy feature of the Jacalitos anticline is that it plunges in both directions into the flank of the Jacalitos syncline.

Castle Mountain fault zone.—The main structural features of the southwestern part of the territory mapped are the Castle Mountain fault zone and the Pyramid Hills anticline, the Avenal syncline, and the Diablo anticline. The first named is a very important and complicated zone of faulting that affected the Vaqueros and older formations. The downthrown side is on the northeast. Faulting along the same zone is the cause of the prominent scarp of Castle Mountain farther west. The fault is not exposed east of Reef Ridge because covered over by the later formations. The lowest of these, the Santa Margarita (?) formation, is only very slightly wrinkled at this point, showing that practically all movement along this part of the Castle Mountain fault ceased before the upper middle Miocene.

Pyramid Hills anticline.—The Castle Mountain fault zone is the locus of an important anticlinal fold that was formed long after the cessation of fault movement along the eastern portion of the zone. The shale of the Santa Margarita (?) formation and the younger formations have been worn off over the summit of the fold, and the rocks exposed along this uncovered axis belong chiefly to the Knoxville-Chico. The disturbance of the pre-Miocene rocks has been so great that the axis of the anticline is not easily traceable within the faulted zone. To the southeast the general zone of faulting gives place along a divergent axis to an overturned anticline in the Knoxville-Chico beds, and this is traceable into a regular, sharp fold covered by the shale of the Santa Margarita(?). This is the anticline forming the prominent ridge of the Pyramid Hills and the northeastward-tilted

monocline of the southern end of Reef Ridge and the Kreyenhagen Hills.

Avenal syncline.—On the southwest the flank of the anticline just described dips down into the Avenal syncline, which determines the position of McLure Valley. North of Avenal Creek this syncline is an extremely sharp fold, overturned and much disturbed beyond the area of the map, but gradually plunging and becoming shallower toward McLure Valley.

Diablo anticline.—Southwest of the valley the beds rise again steeply on the flank of the Diablo anticline, which is a steep fold plunging rapidly toward the southeast and forming Avenal Ridge, the end of the Diablo Range. Its axis was once overarched by the Santa Margarita (?) and later formations, but is now denuded of these formations and exposes greatly disturbed Knoxville-Chico beds. This anticline is one of the main axial folds of the Diablo Range.

CHARACTER OF THE FOLDS AND FAULTS.

The folds and faults in this region are almost invariably plunging and curving. Most of them represent important and continuous structural lines along which movements of locally varying amount and direction have taken place. The anticlines are, as a rule, asymmetric elongated domes, with broad summits and dips increasingly steep away from the axis, but with varying limits of angle on the two sides and at different points along the longitudinal extent of the fold. The synclines have a reciprocal character. Several of the anticlines, notably the Coalinga, Jacalitos, and Pyramid Hills anticlines, are so formed that there may be traced on one or the other flank an axis along which the dip away from the summit of the fold steepens markedly. Such a structure indicates an inclined position for the main axis of the fold. The inclined axis of the Coalinga anticline is overturned at one point along Oil Canyon, and overturns occur likewise along the Pyramid Hills anticline, the Avenal syncline, and on the northeast flank of the Diablo anticline. An important feature of the structure of the district is that the northern portion of the axis of the Coalinga anticline and the axis of the Jacalitos anticline lean toward each other, the former toward the southwest and the latter toward the northeast, as if owing to a compressional force from the two sides toward the Coalinga syncline. The Pyramid Hills anticline is analogous in this respect to the Coalinga anticline northeast of Pleasant Valley and seems to be opposed in a similar way across McLure Valley by a contrary thrust in the Diablo anticline. The two latter folds have, however, not been studied in detail.

In regard to the character of the faults in this region little can be said, owing to the fact that the areas of older rocks in which they chiefly occur were examined only by way of reconnaissance. With

regard to the Los Gatos Creek and Castle Mountain fault zone, the planes of movement have been many and the resultant downthrow in each case is on the northeast.

GEOLOGIC HISTORY.[a]

GENERAL FEATURES.

The portion of geologic time of which the rocks of this part of the Diablo Range afford a record is comparatively late. The oldest rocks that appear in the axis of the mountains and that form a basement on which the later ones rest probably go no further back than Jurassic time, but even in them the record is obscure. Traces of preexistent rocks are to be found as inclusions in the younger formations, but they tell nothing of the age and give only suggestions as to the character of the terranes that must have formed land surfaces somewhere within this region during pre-Jurassic time. The history of the later periods, however, is preserved in considerable detail in a great series of strata that represent probably the greater portion of the time from the beginning of the Cretaceous to the present. These have been periods of great activity during which earth movements affecting broad areas, but at the same time causing various effects locally, have resulted in continually changing conditions and produced a complicated record.

JURASSIC (?) PERIOD.

The earliest period of which there is definite record is that of the Franciscan formation, of which the age or extent in time is not known, but which is doubtfully referred to the Jurassic. The conditions that prevailed during this period were probably those of widespread marine deposition, although the absence of remains of organisms in the rocks leaves this origin in doubt. The Franciscan sediments were laid down to a great depth over a very extensive area covering much of the present Coast Range region, and are generally similar, fairly fine grained materials, consisting largely of fine sandstone, dark clay shale, and jasper. The natural conclusion to be drawn is that the open ocean occupied much of this region in the Franciscan period. The source of the materials is unknown.

At the close of or perhaps in part during the period when the sediments of the Franciscan were being laid in beds at the bottom of the basin of deposition, they were intruded by immense bodies of molten rock of a basic variety that has since been changed into the serpentine so abundant over the areas in which the rocks of this formation occur, and other igneous intrusions probably took place

[a] A brief discussion of the geologic history of the Diablo and Temblor ranges is given by F. M. Anderson in his "Further stratigraphic study in the Mount Diablo Range of California" (Proc. California Acad. Sci., 4th ser., vol. 3, 1908, p. 6).

some time during the same general period. It is not possible to state the character of the further events or the length of time before the arrival of the period represented by the Cretaceous beds. There is no incontrovertible evidence that any of the intrusive or metamorphic activity took place after the latter period commenced.

CRETACEOUS PERIOD.

The oldest Knoxville-Chico beds probably represent an early part of Cretaceous time. The strata that began forming in this period were similar to those of the Franciscan formation, and the prevailing conditions were probably not greatly different in the two periods. The sea spread widely over the Coast Range region, probably covering much of it to a considerable depth, and coarse and fine sediments derived from a land area whose position and character are doubtful were alternatingly laid down to form the present interbedded shale and sandstone of the lower two-thirds of the group. Remains of organisms are rare in these beds, but where found indicate their marine origin and Cretaceous age. The general scarcity of fossils may indicate a fairly deep water origin for the beds. There is no evidence that many fossils once present have been obliterated by crushing or leaching. The beds contain little calcareous material and in many places remain without sign of great disturbance. In the higher portion of the Cretaceous coarser and probably more littoral beds predominate and fossils are somewhat more abundant.

The amount of information that has been obtained from the Cretaceous deposits of the Coalinga district does not warrant the formulation of a definite outline of the history of that period. One or more epochs of uplift of the strata above the sea and prevalence of land conditions probably intervened between long epochs during which the great depth of sediments was accumulated, but the length of these different epochs has not been determined. During the early portion of the Cretaceous fine materials were by far the most abundant, fine silt alternating rapidly with fairly fine sand. During the later portion sand was more abundant. The later portion of Cretaceous time is not everywhere represented in the district at the present day, owing either to the land having been above water or to the subsequent removal of the deposits. The conditions during those periods in which deposits were being formed were equable and resulted in the formation of homogeneous masses of strata of great thickness. The great zone of conglomerate that has been described as lying in the middle of the lower or predominantly fine-grained portion of the group represents a remarkable change of conditions. It means that a land area, of rocks in part dissimilar to those now outcropping in the Diablo Range, was in close proximity, and it

probably indicates a considerable break in time between its age and that of the beds below it.

The total thickness of the beds formed during the Cretaceous that are still within the district is at least 12,800 feet. They have become compacted since their deposition, and perhaps the original beds are not all present in the sections measured, so that this thickness is probably less than the amount of vertical subsidence that the land must have undergone to allow their deposition. The homogeneity of the successions of strata through great thicknesses shows that the source of the material and the general conditions did not greatly vary. The basin of deposition must have been subsiding gradually with reference to a fairly constant or rising area of land.

EARLY TERTIARY PERIOD.

The greatest diversity of movements and conditions that is recorded for a period in the Coast Ranges is that which throughout characterizes the Tertiary. In some places the era opened under conditions continuing those of the late Cretaceous, and in the very northern part of the Coalinga district the beds belonging to the period close to the line between these two great time divisions are as yet only with doubt referable to either the one or the other. There is, however, a great faunal hiatus between the uppermost Cretaceous fossiliferous bed (Chico) and the lowermost Eocene fossiliferous stratum (Tejon), which must represent a long period of time. In contrast to the seeming intergradation of the Chico and Tejon in the region north of Alcalde Canyon is a profound unconformity between the Eocene and older Cretaceous beds farther south; and this overlap occurred within a small central portion of the Coalinga district. Either the interval of time that probably intervened throughout this region between the portions of Cretaceous and Eocene time here represented was occupied by the erosion of the upper portion of the Knoxville-Chico in the southern part of the field, or else the southern area of Cretaceous was continuously above water during the time occupied by the deposition of the Upper Cretaceous beds in the northern part of the district. Evidence was not gathered sufficient to decide which of these conditions was the more likely. Whereas the source of the sediments during Jurassic and at least earlier Cretaceous time is doubtful, the great land area and most important source of detritus having possibly been toward the east, the Coast Range belt of relief is known to have dominated the later formations, and the present Great Valley region, at least in later Tertiary time, is known to have played an active part as a basin of depression.

During the Eocene the region of the Coalinga district occupied a littoral belt east of the Coast Ranges and at least for a portion of the

time shore-line and estuarine conditions prevailed in the vicinity of Coalinga. At the coal mines in the Alcalde Hills the beds that give evidence of such conditions are especially well exposed. They are roughly bedded, of varying coarseness, full of gypsum and alkaline salts, and interbedded with lignite, showing that the materials accumulated roughly not far distant from the shore in shallow, brackish water. Elsewhere, as along Reef Ridge, the shallow-water character of these beds is less pronounced. The fossil remains in the lower portion of the Tejon (Eocene) formation show that mollusks lived abundantly in the sea and that other forms, such as echinoderms, corals, and bryozoans, were likewise present.

It is possible that the marine conditions were exchanged during a long or short period for land conditions before the deposition of the shale beds in a later period of the Eocene, but little evidence on this point has been obtained. In that later period the land probably sank and the shore receded, the source of supply of coarse materials being removed partly by this recession and partly by the base-leveling of the land. The deposits on the sea bottom were formed jointly by fine sediments and minute organisms such as diatoms and foraminifers that lived in the sea and dropped in great numbers to the bottom after death. In the mud that was thus formed on the sea floor the organic matter inside the shells of these little plants and animals must have become buried and been preserved. From this source the petroleum that seems to have originated in the Eocene shale is thought to have been derived. Other forms of life that inhabited the sea were delicate little mollusks, which probably lived in the mud at the bottom, and fishes, the scales of which are preserved.

The whole of the formation that was deposited during the Eocene is not preserved in the Coalinga district, owing to a great uplift of the land that brought the marine conditions to an end and subjected the formation to erosion. It is therefore impossible to state what length of time or how large a portion of the Eocene was occupied with deposition. There is no direct evidence whether or not the formation extended beyond the limit of the Eocene into the Oligocene. The greatest thickness of the beds belonging to the Tejon (Eocene) formation that has been preserved within the district is exposed on Joaquin Ridge north of Coalinga, where it amounts to at least 1,850 feet.

The land movement that caused the emergence of the area over which the Tejon formation was laid down during Eocene time was not merely of a local nature but is known to have affected a large portion of the coastal province. As a result of it the Eocene strata were upheaved and in places, notably near the axis of the Coalinga anticline south of Oil City and along the western border of what is now Pleasant Valley, were steeply tilted. Movements probably took place at that time along some of the lines of structure which have

been the loci of more recent disturbances, and at that time also some of the features of the present Diablo Range were determined. During most and probably all of the Oligocene period the region of the Coalinga district, as well as a much greater portion of the southern Coast Ranges, was land and the Eocene and older beds were exposed to erosion. As a result large parts of the pre-Miocene formations were worn away and parts of the surface planed off.

MIDDLE TERTIARY PERIOD.

Early in the Miocene the area of the eastern flank of the present Diablo Range became pretty generally submerged to a slight depth below the sea, and the worn surface of the older formations became the floor upon which the marine deposits of sand, pebbles, clay, and shells were formed that have been described as the Vaqueros formation (lower Miocene). During this period land areas probably remained in the northwestern and southwestern portions of the region that is now the Coalinga district. In the northern part of the district coarse shore deposits were formed at the beginning of the period. In the southern part the deposits were littoral but less markedly so, the basal beds being in places more fine grained than those above them. The greater part of the period was taken up by deposition of medium-grained sand materials within a littoral belt. Among the living organisms that flourished in this belt we know from the abundant remains that mollusks and echinoderms existed in great numbers. They were of species characteristic of the early portion of Miocene time throughout the coastal region of California. Remains of trees were abundantly preserved in the gravel and sand deposits, supposedly of lower Miocene age, that form a capping on the flanks of Juniper Ridge. These deposits were laid down upon a level surface that had been worn in the Cretaceous rocks and may have originated in part on a land area adjoining the shallow sea waters. At one stage in the middle portion of the period a peculiar change of conditions that is not easily explainable took place in the northern part of the district. Coarse materials ceased to be deposited, and practically the only materials that were laid down were the remains of diatoms and foraminifers mixed with extremely fine silt. As a result the 15 to 20 foot "indicator" bed was formed. In the succeeding stage in the same area fairly coarse sand somewhat resembling beach sand was the chief material deposited, and the remains of a near-shore marine fauna, consisting chiefly of mollusks, were preserved. A rough measure of the Vaqueros (lower Miocene) period is afforded by the thickness of the strata laid down. The compact beds of Reef Ridge have a maximum known thickness of about 900 feet.

The relation of the formations on the two sides of the Castle Mountain fault has an important bearing on the questions involved

in the history of the early Miocene as well as other periods. The Eocene and lower Miocene formations stop near the south end of Reef Ridge at this fault zone, and first appear again on the southwest side of this fault 7 miles south of Little Tar Canyon on the southwestern edge of McLure Valley.

The hypothesis that seems best to fit the conditions outlined above postulates that the region west of the fault must have been thrown up as a great block or series of faulted blocks during the period of movements following the lower Miocene, and that the Eocene and lower Miocene beds that had been formed over it were almost completely eroded away and the fault block completely reduced during the early middle Miocene land period.

No faulting has taken place along this portion of the fault line since the early middle Miocene, as is proved by the fact that the later beds are unaffected. The prominent fault scarp of Castle Mountain a few miles northwest may be due to more recent movement along the fault there while it has been stationary near Reef Ridge. Unless such a movement has taken place the prominence of this topographic and structural feature would tend to favor the latest possible date for movement along the fault zone as a whole, namely, the early middle Miocene.

The deposition of beds in the Vaqueros (lower Miocene) period was brought to an end by movements which, it is thought, left the land in this portion of California not far above the sea, so that in the succeeding middle Miocene period no great amount of sediment was removed from this region to the wide expanse of sea farther west, in the region now west of the Salinas Valley, in which the fine, largely nonterrigenous ooze of the Monterey shale was laid down. As a consequence, the Vaqueros beds were locally well preserved, and when the time came for later sediments to be laid down upon them there were preserved at the contact no striking evidences of the time that had elapsed. Good structural evidence, in addition to that of paleontology, that a time interval and erosion did occur, however, is afforded by the varying thickness and locally complete absence of the Vaqueros, the deposits of the upper middle Miocene (Santa Margarita (?) formation) overlapping upon different horizons and in places directly upon the pre-Miocene rocks. In the region of the Stone Canyon coal mine, near the summit of the Diablo Range, west of the Coalinga district, the shale of the Santa Margarita (?), which is supposed to be the equivalent of the shale referred to the same formation in Reef Ridge, lies with distinct unconformity upon the tilted and eroded lower Miocene beds, showing that there, too, a land period came between.

In the northern portion of the Coalinga district it is not impossible that there have been preserved in the Big Blue, in its sands and coarse

gravel and strange serpentine detritus, accumulations that took place during a portion of this interval between the marine invasions of the lower Miocene and later middle Miocene.

It will be a matter of considerable interest to determine to just what age the Big Blue belongs, both on account of its bearing on the history of the Monterey period and because it is the earliest zone giving indubitable evidence of the occurrence in it of fragments of the rocks associated with the Franciscan formation. On the northern flank of Joaquin Ridge this zone is composed almost entirely of serpentine fragments of all sizes derived from a near-by area in which the Franciscan was exposed. It is very probable that this area was in the same position as the present serpentine area on Joaquin Ridge and was brought to the surface by post-Eocene folding along the line determining the axis of the present Coalinga anticline and by erosion over the area thus uplifted. There is no proof that the Franciscan formation or its metamorphic associates appeared at the surface in this district in any preceding period.

After the early portion of the middle Miocene period had elapsed a great subsidence took place and brought the whole southern part of the district below a deep sea. The subsidence there was probably progressive from south to north. In the region of the present Temblor Range south of the Coalinga district the Monterey (early middle Miocene) period is represented, and the subsidence there may have continued through most of middle Miocene time, allowing a very great thickness of shale beds to be formed. If such is the case, the area of subsidence widened toward the north until it affected the southern part of the Coalinga district in the latter portion of the middle Miocene period and caused the deposition of deep-water shale beds as a continuation of the upper portion of the series farther south.

The conditions that prevailed during the period of deposition of the shale of the Santa Margarita (?) formation must have been similar to those of the later part of the Tejon (Eocene) period already discussed and to those prevailing during Monterey (middle Miocene) time over a considerable portion of the Coast Ranges.[a] Organic remains are not well preserved in the shale of the Santa Margarita (?) formation of the Coalinga district, but it is almost certainly largely composed of siliceous and in lesser amount calcareous remains, of diatoms and foraminifers, respectively.

In the northern portion of the district the subsidence during the Santa Margarita (?) period was not so great and coarse shallow-water sediments were laid down. For a portion of the time there thrived here a fauna of strong-shelled mollusks, barnacles, and echinoderms

[a] For an outline of the history of this period elsewhere see Fairbanks, San Luis folio (No. 101), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 9; and Arnold and Anderson, Geology and oil resources of the Santa Maria oil district, California: Bull. U. S. Geol. Survey No. 322, 1907, p. 67.

(sand dollars), fitted to survive in troubled waters along shore. This subsidence may have immediately preceded or been contemporaneous with that in the area of the Kreyenhagen field.

The thickness of strata deposited during the Santa Margarita (?) period in the region around the modern Pleasant Valley was about 600 feet (exclusive of the Big Blue). The shale in the southern part of the district was laid down to a thickness of as much as 1,200 feet.

LATE TERTIARY AND EARLY QUATERNARY PERIOD.

The close of the Santa Margarita (?) period witnessed an uplift of the land over the large region that its deposits covered, and the beginning of a long period, occupying most of the rest of Miocene time, during which shallow-water deposits were formed in arms of the sea that were separated from each other by land areas coincident in large measure with the more elevated portions of the present Diablo Range. Probably an interval succeeded the Santa Margarita (?) period during which the area of the Coalinga district was not submerged, but no measure of its length has been obtained and it can not have been as long as the previous interformational periods that have been made out. It is thought to have been longer in the northern than in the southern part of the Coalinga district. The great succession of littoral marine sand, gravel, and clay beds that followed mark a gradual subsidence during the Jacalitos and Etchegoin periods, which are the equivalent of upper Miocene time. This subsidence was probably effected by a gradual process of downfolding in basins of depression that crossed a belt of topographic relief corresponding to the present Diablo Range, and in the large basin of the San Joaquin Valley. The mountainous tracts of the older formations were probably at the same time subject to uplift that caused them to preserve a fairly uniform relation to the sea area and resulted in a comparatively stable position of the shore line. Roughly speaking, the Diablo Range may be said to have existed as a row of islands. The continued presence of these islands preserved the littoral character of the beds which were laid down along their shores and which were later upheaved to form the present fringe along the eastern base of the Diablo Range. The belt of lowland bordering the mountains must have been occupied for part of the time by arms of the sea in which estuarine conditions prevailed and in which large amounts of gypsum and alkaline salts were precipitated. The thickness of the deposits that were laid down under these conditions, in the Jacalitos and Etchegoin periods, amounts to over 7,000 feet, and may be taken as a rough measure of the time that elapsed and of the depth to which the basal platform of the basin or basins sank. The beds of this age are preserved in large part in their original incoherent state and their thickness does not represent as much deposition as a similar thickness would in the consolidated beds of some of the older formations.

The conditions outlined above did not prevail uninterruptedly during the whole of the period represented by the Jacalitos and Etchegoin combined. There probably were many oscillations in the orogenic movements and complex variations in the areas and degrees of movement, in the land areas, and in the conditions of climate and supply of sediments. Such changes are attested by the variety of the beds and zones of deposits that were formed, and by the presence within the series of strata that originated in fresh water or on land, but are far too complicated to be made out in detail. There was at least one period, the close of the Jacalitos, when a marked disturbance took place. In the northern part of the region under discussion the sea spread much farther westward before the beginning of the Etchegoin, causing the beds of that period to overlap beyond the limits of the Jacalitos and to be laid down unconformably upon the Cretaceous and Franciscan. It is possible that an uplift had preceded the subsidence that caused this overlapping and had raised the earlier upper Miocene beds above the sea, allowing them to be eroded; but somewhere within no great distance the marine conditions and sedimentation must have been continuous, and the appearance of conformity between the Jacalitos and Etchegoin formations on Joaquin Ridge and in the Kreyenhagen Hills indicates that at this distance from the axis of the mountain belt to the west deposition went on without interruption. The much greater thickness of the formations south of Waltham Creek than north of it points to episodes in the history of the northern region that have not been made out. Probably the progress of sedimentation was broken at different periods in the northern region when continuous in the southern, the line at present followed by the southern end of Curry Mountain and the lower portion of Alcalde Canyon having been a locus of changes separating areas of different geologic history.

The kinds of organisms that lived in the upper Miocene period and left relics in the rocks were principally mollusks and echinoderms, the latter including both sea urchins and sand dollars. Cirripedia (barnacles), brachiopods, and corals were also common at certain times, and fishes and sea mammals (either cetaceans or sirenians) left a record in their teeth and bones. A great abundance of fossil wood is preserved in the near-shore gravel and sand beds that were formed during the Jacalitos (early upper Miocene) period, and in one place the tooth of an extinct species of horse is associated in the same zone. The conditions throughout most of the period were favorable to marine life and rich faunas were preserved.

The Etchegoin (late upper Miocene) period was brought to a close by a gradual uplift of the land and transition from locally varying

open-sea and estuarine conditions to more generally prevalent estuarine and perhaps also brackish-water conditions. The faunas reflected this change and the sediments became thoroughly impregnated with and in places largely made up of salts, especially gypsum. The marine body of water gave place in turn either through a direct transition or after the intervention of a land period to fresh water at the beginning of the Tulare period, which includes most of Pliocene time and probably a part of the early Pleistocene. The origin of the deposits of this period and the conditions prevailing during it have been discussed above in the description of the formation. Suffice it to say here that the character of the period is in doubt, but that the stage with which it opened was not of long duration; that the course of events following that stage probably did not differ greatly from present history; and that the period was probably largely taken up in deposition of sediments subaerially over the topographic basins, gradual subsidence of the basins, and temporary incursions of the sea into them. Deposits of various kinds, fresh-water, subaerial, and marine, were built up into one conformable succession of beds with a thickness of as much as 3,000 feet or more. The period ended in great orogenic movements that caused the greater part of the disturbance now visible in the post-Eocene formations. The Tulare beds and all those below them were warped into folds and tilted at high angles. Similar movement took place widely along the Pacific coast early in the Quaternary, and the disturbances here may be ascribed to the same general epoch of activity. It is partly on the basis of this correlation of movements that the Tulare period is considered as extending into Quaternary time. The previous greatest periods of movement of which record has been obtained in the Coalinga district were at some time in the later half of the Cretaceous and at the close of the Tejon (Eocene). The relative importance of these movements is hard to estimate. It would appear from the fact that all the post-Eocene beds up to the Quaternary have been so violently displaced, the youngest as much as the older ones, while the earliest formations are not everywhere greatly disturbed, that the movements following the Tulare period were the most profound of all. But it must be borne in mind that the compact older formations have acted as a buffer against which the late movements have crushed the little-consolidated and therefore pliant later strata, and that great disturbance in the Tertiary and later beds does not necessarily represent as great a causal force as slighter displacements in the great homogeneous and compacted series of older rocks, such as those belonging to the Cretaceous. This principle being taken into consideration, and the great amount of disturbance in most places in the Cretaceous beds due to forces acting in a period preceding the Miocene being noted, it may be

conceded tentatively that the greatest orogenic movements were of pre-Miocene date. The strata on the flanks of Juniper Ridge may be cited as an example of the comparative amount of deformation produced in some places by the different movements. The Cretaceous beds there were steeply tilted before the Miocene, and the Vaqueros (lower Miocene) strata that were laid down over their eroded edges have been uplifted with only gentle tilting in the subsequent periods, whereas only a couple of miles eastward, where not protected by the solid foundation of Cretaceous rocks, the Miocene beds have been sharply folded and faulted. The movements following the Tulare resulted both in broad tectonic uplift and in local warping along the axes of upward movement that determine the present mountain and hill tracts. But these axes had already existed for a long time and the broad features of the mountain regions had been outlined in the previous epochs of movement.

LATE QUATERNARY PERIOD.

The processes that are taking place at the present time are a continuation of those that have been active since the end of Tulare time. During the later Quaternary the great basin of the San Joaquin Valley was continually receiving the wash from the mountains, and approximately horizontal deposits similar to those of the Tulare formation were being laid down over the valley floor. They must have accumulated to a depth of many hundred feet in this and the smaller valleys as well. During this period the mountainous tract was being worn down; but at the same time it underwent a gradual uplift that kept pace partly with the wasting away. It is not known how great a portion of Quaternary time the Tulare period may have occupied, but judging by the amount of movement along the structural axes, erosion of the mountains and hills, and aggradation of the valleys that has taken place since its close we may conclude that most of the Quaternary has been consumed in the subsequent events. Some other features of the geologic history are outlined in the sections dealing with the physiographic development and the faunas.

THE DEVELOPED TERRITORY.

HISTORY OF DEVELOPMENT IN THE COALINGA DISTRICT.[a]

The attention of oil men was early called to what is now known as the Coalinga oil district by a "live" oil seepage on the south line of sec. 17, T. 19 S., R. 15 E. of the Mount Diablo base and meridian, at a point about 1,000 feet east of the southwest corner of this section.

[a] Many of the data concerning the early developments in the Coalinga district have been obtained from written communications of W. W. Orcutt and from accounts given by W. L. Watts in bulletins 3 and 19 of the California State Mining Bureau, published, respectively, in 1894 and 1900. The work of G. H. Eldridge has also brought to light some information which is here included.

At this point a considerable quantity of light oil of a greenish color came up through the shales. It is said that in the early seventies this oil was collected in pits and there refined in a small way.

The early prospectors believed that this seepage had its source in a productive oil sand, but they did not know its extent, its depth below the surface, nor in what direction the sand lay from the seepage, for at this point the strike of the shale swings abruptly from a nearly north and south line to an easterly and westerly direction.

The first successful development work in the Coalinga district took place in the Oil City field about 1890. At this time the Coast Range Oil Company, of Los Angeles, sunk a well 163 feet in the purple shale of the Chico formation in the northern part of sec. 20, T. 19 S., R. 15 E., from which gas and a little greenish oil of light specific gravity is said to have flowed. A windmill pump was attached to this well, and 10 barrels of oil was pumped from it daily for two days, after which the production fell gradually.

In 1891–92 four wells were drilled in the same vicinity by Messrs. Rowland and Lacy, of Los Angeles, but only one of these was successful. It was 400 feet deep and yielded 9 barrels of oil daily.

W. L. Watts visited the district in 1893, gathering material for his report on the San Joaquin Valley oil districts,[a] and reports that at that time he found five wells in the Oil City region, three of which were plugged and in two of which oil or gas was rising. The prospects for a great field were therefore not encouraging at that time.

In 1895 the Producers and Consumers Oil Company, of Selma, organized by J. C. McClurg and others, sank two wells a short distance southeast of the wells of Rowland and Lacy, which yielded 15 and 20 barrels of 34° Baumé oil per day.

In 1896 Chanslor & Canfield drilled three wells in the southern part of sec. 17, T. 19 S., R. 15 E., just north of the sites of the original Oil City wells, and were rewarded with small producers. They then took over the property of the Producers and Consumers Oil Company in the NW. ¼ sec. 20 and drilled a well 300 feet east of the old wells and struck oil sand at 890 feet, which yielded 300 barrels of oil per day. This was the first big well of the district.

The Clear Field Oil Company, a branch of the Union Oil Company of California, drilled a well in the southeast corner of sec. 18, T. 19 S., R. 15 E., in 1897. This well was 1,100 feet deep and showed only a trace of oil.

In 1897 the Home Oil Company, of Selma, entered the field and began drilling still farther east or farther down the dip of the strata, and completed a 1,400-foot well (the famous Blue Goose), which is said to have flowed from 500 to 1,000 barrels of oil per day and to have maintained a production of 250 barrels per day as late as August,

[a] Bull. California State Min. Bur. No. 3, 1894.

1900. Unsuccessful wells were drilled in the Westside field during this year, among them being that of the Sunnyside Oil Company, now the Henshaw water well.

In 1899, after the completion of the Blue Goose well, several other companies commenced operations in the Oil City field, but with indifferent success or failure. The most important event in development during this year was the drilling of water wells by J. A. McClurg in the SW. ¼ sec. 16, T. 20 S., R. 15 E., the water thus obtained being piped to the Oil City field and the region to the west.

The development of the Eastside field began in 1900 with the drilling operations of the Independence, Oil City Petroleum, Twenty-eight, Caribou, and other companies. During the same year several prospect holes were put down in the Kettleman Hills and Kreyenhagen fields. In the latter field several more or less productive wells had been put down a short time previously. Between 1900 and 1907 no developments of consequence took place in the Kettleman Hills and Kreyenhagen fields, but in 1907 and since then up to the present time more or less activity has been displayed in the region south of Waltham Creek, and such wells as the Golden Crest and El Cerrito have attempted to obtain oil in formations overlying the Santa Margarita (?), but so far without success.

Successful development work was begun in the north end of the Westside field in 1901, when the Mercantile Crude, Commercial, Call, Main State, and other companies started drilling. Exploitation was gradually carried southward until the region as far as the Esperanza lease in the SW. ¼ sec. 6, T. 20 S., R. 15 E., was proved. The unsuccessful Blue Diamond hole in the NE. ¼ sec. 26, T. 20 S., R. 14 E., was also put down about this time, and tended to discourage development in the southern part of the western field.

In 1902 the California Oilfields (Limited) entered the Eastside field and soon began active operations in secs. 21 and 27, T. 19 S., R. 15 E. Development work was still carried on in the Westside field, but the decline in the price of oil was at this time beginning to show its effects on the development.

Notwithstanding the low price of oil, which reached as low as 15 cents per barrel in 1905, drilling operations were carried on continuously throughout certain parts of the field from 1902 to 1906. In the fall of 1906 the Lucile well was brought in as a strong producer, thus proving the south end of the present Westside field. Beginning with the impetus that this discovery gave to development and encouraged by the gradually bettering conditions of the oil market, exploitation throughout the Coalinga field went ahead rapidly until in the summer of 1908 about 100 wells were being drilled simultaneously in the district. Mention should be made of the influence of the operations in the northern part of sec. 34, T. 19 S., R. 15 E.,

which were carried on in 1906 and 1907, by the late Mr. W. P. Kerr and associates. The wells brought in by these men are the most productive in the district. During the latter part of 1906 and the beginning of 1907 these and practically all the other independent wells in the Eastside field, with the exception of those in section 22, were absorbed by the California Oilfields (Limited) or by the Standard Oil Company, which had entered the field as a producer.

An important event in development in 1908 was the completion of the T. C. Oil Company's well in sec. 2, T. 19 S., R. 15 E., which extended the proved territory of the Eastside field 2 miles northward. Among the developments of importance in 1908 and 1909 were the series of exceptionally productive wells of the American Petroleum Company drilled along the eastern edge of the proved Westside field, and the wells of the Nevada Petroleum Company drilled still farther east, which showed zone B to be unproductive in that territory but which encountered productive beds in zone D. In September, 1909, the Silver Tip No. 1, in sec. 6, T. 21 S., R. 15 E., came in as a gusher and produced at the rate of about 20,000 barrels a day for several hours. This well drew the attention of oil operators to the south end of the Westside field, and its completion was followed by renewed activity in sec. 12, T. 21 S., R. 14 E., and sec. 18, T. 21 S., R. 15 E.

AREAS DISCUSSED.

For convenience of discussion the Coalinga district has been roughly divided into five fields or regions, and these into lesser subdivisions or areas. The major subdivisions are as follows: (1) The Oil City field, lying in Oil Canyon near the north end of the district; (2) the Eastside field, embracing the territory northeast of Oil Canyon and including Anticline Ridge; (3) the Westside field, extending southeastward from Oil Canyon as far as Alcalde Canyon; (4) the Kreyenhagen field, which includes the Jacalitos and Kreyenhagen hills, Reef Ridge, and the territory southward to the Kings County and Kern County boundary; and (5) the region of the Kettleman Hills, extending from the Guijarral Hills southward to the gap separating the Kettleman Hills from the Lost Hills.

OCCURRENCE OF THE PETROLEUM.

The following is a brief summary of the conditions of occurrence of petroleum in the Coalinga district, and is inserted here as introductory to the detailed and necessarily more local discussion concerning each particular field, which follows.

FORMATIONS IN WHICH PETROLEUM OCCURS.

Petroleum occurs in five different formations in this district—the purple-shale member of the Chico (Upper Cretaceous), the Tejon (Eocene), Vaqueros (lower Miocene), Santa Margarita (?) (upper

middle Miocene), and Jacalitos (upper Miocene). In the first two the oil is thought to be primary—that is, it is believed to have originated in the formations; in all the others it is secondary—that is, it has come into them from some outside source since their deposition.

OIL ZONES.

General description.—Within each of the formations mentioned are one or more oil-bearing zones consisting either of more or less extensive layers of sand or gravel or of local lenses of the same materials, which can be traced in a general way over large areas. The oil sands in the Chico will be referred to collectively as the Chico oil zone; those in the Tejon as the Tejon oil zone; those in the lower part of the Vaqueros as the lowest Vaqueros zone, or zone D; those in the middle Vaqueros (Eastside field light-oil sands) as the light-oil zone, or zone C; those in the upper Vaqueros (first sand) in the fields northeast of Los Gatos Creek and in the Santa Margarita (?) and the lower Jacalitos in the Westside field south of Los Gatos Creek as zone B; and those in the Jacalitos in the Westside field above the productive basal beds of that formation as zone A. The top of zone B is shown in contour in Plate XV. With the exception of those in the lowest zone in the Vaqueros (zone D) the oil sands are known to consist mostly of more or less local beds or lenses varying in thickness, composition, grain, and hardness from well to well and often showing a puzzling diversity in gravity of product within short distances. Zone D, as would be expected of the basal portion of a widespread formation, partakes of the same general characteristics throughout nearly its entire range within the district—that is, it is generally coarse gravel at the base, with somewhat finer gravel or very coarse sand above this and finally medium-grained sand. The productive beds in the other zones vary from medium fine-grained to coarse pebbly sand or even gravel.

Chico oil zone.—The sandy zones in the lower portion of the purple-shale member contain commercial quantities of oil on the Coalinga anticline in the Oil City field. It was the inducement offered by seepages from this member in the Oil City region that led to the drilling of the test wells from which the present district has been developed. The oil in the Chico oil zone is a paraffin oil, usually of light gravity, about 33° to 34° Baumé, and is greenish in color. The thickness of the productive sands is ordinarily between 15 and 60 feet, and the yields are light, 4 to 75 barrels per well per day being the normal extremes of production, although the initial flow of one of the Oil City wells is said to have been 700 barrels per day.

Tejon oil zone.—The Tejon is known to contain accumulations of oil in commercial quantities only in the southern portion of the district, where the oil has gathered in the porous sandstone of the lower

member, below the shales of the upper member, in which it is sup posed to have originated. The productive sandstone outcrops in th steeply dipping monocline of Reef Ridge in the Kreyenhagen fiel Wells have been put down at a number of places, but have obtaine only small quantities of oil from this zone. An amber-colored oil c 45° to 48° Baumé gravity occurs sparingly in the uppermost produc tive Tejon sands of the Oil City field. This is the lightest oil in th Coalinga district and among the lightest in the State.

Vaqueros oil zones.—The principal oil-bearing formation in th Coalinga district is the Vaqueros or lower Miocene. It yields pra tically all of the oil in the Eastside field and a considerable part c that in the Westside field and is thought to contain commerciall important quantities in the Kreyenhagen field and in the region c the Kettleman Hills. The total distance penetrated through th formation by the wells in the Eastside field is about 700 feet, and i the Westside between 300 and 500 feet. The actual productiv sands of course occupy only a relatively small space in this colum usually under 150 feet in the Eastside and under 100 feet in th Westside. Three zones are recognized in this formation, the lowe or zone D, the middle or zone C, productive only in certain parts c the Eastside field where it yields oil up to 31° Baumé in gravity; an zone B, recognized as Vaqueros in the Eastside field and the norther part of the Westside field. The oil from the Vaqueros varies i gravity from 14° to 22° in the Westside and from 14° to 31° in th Eastside. It is black or dark brown and the production averag between 100 and 200 barrels per well per day. One well in th Eastside field is now flowing 3,000 barrels of oil per day and a initial yield of 7,000 barrels in 18 hours was recorded for another we in the same field, but these figures are unusual. The Silver Tip wel in the south end of the Westside field, yielded at the rate of 20,00 barrels a day for a few hours during its initial flow; this is the max mum rate for the district.

Santa Margarita (?) oil zone.—A stratum of sand carrying charac teristic fossils of the Santa Margarita (?) formation immediately ove lies the Tejon (Eocene) in the region of the San Joaquin coal mine i the Westside field, but is so closely associated with lithologicall similar beds of the Jacalitos in the same vicinity that it has bee mapped and discussed with them as zone B. The persistent stratu of fine blue sandy shale found throughout the Eastside field an known locally as the Big Blue is arbitrarily placed in the Sant Margarita (?) formation. The Big Blue in the Eastside field immedi ately overlies the uppermost Vaqueros oil zone, zone B, the top o which is shown in contour on the map (Pl. XV).

Jacalitos oil zones, zones A and B.—The Jacalitos (upper Miocene) formation is productive throughout the Westside field except at the extreme south and north ends and in those wells distant over a mile or so from the outcrop of the sands. In other words, the formation is commercially oil bearing wherever it rests upon or is relatively near the Tejon formation—the source of the oil. The line marking the area of productivity of zone B in the Westside field passes somewhere near the east line of the W. ½ sec. 30, T. 20 S., R. 15 E., for in the American Petroleum wells along the west line of this section zone B is unusually productive, whereas half a mile to the east, in the Nevada Petroleum wells, zone B is practically barren; in the latter wells zone D is the productive zone.

Two oil zones are recognized in the Jacalitos formation, the lower or zone B, which is the productive zone over the southwestern part of the Westside field, and zone A, situated some 200 feet above zone B, which carries tar sands or poorly saturated oil sands. The two zones are generally separated by sulphur water, the "big sulphur," although the most persistent sulphur water in the northern end of the Westside field overlies zone A. Northward in the Westside field the productive sands of zone B are found lower and lower in the series of beds, until in the northern end and at least as far south as the M., K. & T. wells the oil is believed to come from beds in the uppermost portion of the Vaqueros.

FACTORS INFLUENCING ACCUMULATION.

The influence of structure upon the accumulation of the petroleum varies somewhat for different parts of the field, the variation being due, it is believed, to the presence or absence of water beneath the oil zones in the various areas. In general the oil in the purple-shale member of the Chico (Upper Cretaceous) is accompanied by water in the underlying beds, and possibly also in the oil sands far down on the dip; under these circumstances the anticlinal theory of accumulation seems to hold good. The anticlinal theory of oil accumulation assumes that the oil, being of less specific gravity, rises above the water in porous rocks and collects at the highest possible points in upward folds, being there confined by impervious strata arching over the folds. The presence of water, according to this theory, is necessary for the accumulation of oil in anticlines.[a] A modified form of the same theory is apparently applicable to certain monoclines, in which water is associated with oil, such as those in the Westside and Kreyenhagen fields, where, instead of impervious beds overlying the porous sands, the residual or heavy hydrocarbons that are left upon

[a] For a fuller discussion of this subject see The geology and oil resources of the Santa Maria oil district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 322, 1907, pp. 71 et seq.

evaporation of the lighter substances originally in the contained petroleum seal the outcrops and hinder or prevent the escape of the oil from below.

Where no water exists in or is associated with an oil zone, as, for instance, in the deeper portions of the Westside field and in by far the greater part of the Eastside field, the structure apparently plays but a minor part in the accumulation of the oil, the presence or absence of the petroleum in the porous strata of the zone apparently depending entirely upon the presence or absence of the oil-yielding shales of the Tejon (Eocene) below or near the beds in question. If the Tejon is present under any particular sand or zone, then the abundance or scarcity of the oil depends largely upon (1) the proximity of the particular sand to the Tejon; (2) the state of disturbance of the underlying shale of the Tejon, or its relative position (whether unconformable or conformable) to the overlying beds; (3) the degree of porosity and grain of the sands of the zone; and (4) the effectiveness of the barriers hindering the escape of the hydrocarbons (oil and gas) from the oil sands.

Within the tested territory of the Coalinga district it has been found that the areas of Miocene sediments (either Vaqueros, Santa Margarita(?), or Jacalitos) immediately underlain by the shales of the Tejon are oil bearing; that the productiveness of these beds varies roughly inversely with their distance from the shales of the Tejon; that the productiveness is greatest where the Tejon occupies a position of angular unconformity with the Miocene sands or is more or less disturbed, as near the axis of an anticline such as the Coalinga anticline.

FACTORS INFLUENCING GRAVITY.

The gravity of the petroleum at any point in any particular bed is apparently influenced chiefly by (1) the original composition of the oil; (2) the thickness and composition of the media through which it has migrated and in which it is detained; (3) its present or past association with water; and (4) its present distance from the outcrop of the oil-bearing zone or its depth below the surface. Little definite information is now available concerning the effect of many of these factors. It seems in general, however, that the oil loses in gravity by migration either upward through various strata, or along a particular bed, or downward as in the supposed migration of the oil from the upper shales to the lower sandstones of the Tejon; that it loses on association with water; that within certain limits oil decreases in gravity up the dip, owing probably to proximity to the surface, with the accompanying facilities for the escape of certain of the hydrocarbons; and that, other things being equal, the finer the grain of the containing reservoir the better the oil will retain its original quality.

RELATIONS OF WATER TO OIL.

The most important question next to that of the actual occurrence of the petroleum in any field is the relation of the water sands to the sands containing the oil. One or more sands carrying water are almost invariably encountered above the Miocene oil zones in the wells of the Coalinga district. The continuity of these sands can seldom be traced far, and they are believed to be for the most part disconnected lenses rather than far-reaching beds. An examination of the surface outcrops leads to the same conclusion. The contents of these upper water sands are believed to be surface or secondary water; that is, water which has percolated into them since they were tilted into their present position and their edges were exposed. This secondary water is seldom under much head, although in a few wells it has been known to flow with considerable energy.

One of the most persistent layers or zones of water is the one termed the "big sulphur," a malodorous blackish fluid met with in or above zone A in the Westside field north of Los Gatos Creek, and between zones A and B south of Los Gatos Creek. No productive oil sands occur above this sulphur-water sand, though one or more tar sands are found over it in places; it may therefore be considered the limit of the upward migration of the oil, at least in commercial quantities. A similar and fully as persistent zone of sulphur water is encountered immediately above the second oil zone, zone C, over a large part of the Eastside field. The sulphur content of these waters probably bears an intimate relation to the oil, for in all of the seepages in this field where the oil is accompanied by water the latter is heavily charged with sulphur. However, not all of the sulphur springs in the region contain oil, so there is a possibility that the sulphur even in this particular sand had an origin independent of the petroleum.

In all of the wells in the Westside field in which the Jacalitos or upper Miocene oil zone (zone B) can be recognized that zone is immediately underlain by a stratum of water. For various reasons it is thought that in this case also the water is secondary and has come into the formation since the passage of the oil from the Tejon (Eocene) into the Miocene. Except in a very small area in the Eastside field no water has so far been reported from below the lowest Vaqueros oil zone (zone D), which indicates almost conclusively that water was not the elevating force for the oil of zone D; it also strengthens the conclusion that the water in the higher zones is surface water that has percolated from the outcrops in the local catchment basin, rather than primary water that has been in the beds since their deposition or water that has come up from below under hydrostatic pressure. Small quantities of water are encountered between the base of the uppermost or fine-grained stratum, bearing light-gravity oil, and

the coarser stratum, carrying heavier oil, which underlies it in zone D in the region of section 6, at the south end of the Westside field.

ORIGIN OF THE PETROLEUM.

The oils of the Coalinga district are believed to have been derived from two different sources, namely, the organic shales forming the uppermost member of the Chico (Upper Cretaceous) and those described as the upper portion of the Tejon (Eocene). It is believed that the oil originated from the organic matter, both vegetable and animal, once contained in these beds. The shales are composed in large part of the tests of foraminifers and diatoms, and a smaller number of other organisms, in such abundance as fully to warrant the assumption that the animal and vegetable material that must have been contained in them when deposited was adequate for furnishing a quantity of hydrocarbons and other compounds more than equivalent to the quantity of petroleum found in this field.

The purple-shale member of the Upper Cretaceous is saturated with petroleum, and its interbedded sands have proved to be productive reservoirs. Practically all the free oil of this member seems to have collected in the sandy zones in the lower portion, none passing below them and little or none entering the beds overlying this member. The overlying beds are of dark, compact clay, moist at least surficially and probably throughout, which it is believed would not allow the escape of much oil. Thus, owing to the presence in the shale of zones favorable for the absorption of the oil and of superjacent beds unfavorable to its escape, it has been retained within the purple-shale member where it is thought to have originated. Both for this reason and because the uppermost member of the Cretaceous is limited to a small area in the northern part of the district we must look to some other source for the oil occurring in the Eocene and higher. Furthermore, the petroleum of the purple-shale member of the Cretaceous is of a very different character from that obtained from the later beds, as will be seen upon examination of the analyses made by Irving C. Allen (pp. 267–272). Samples numbered 21, 23, and 24 were obtained from wells of the Coast Range, Coalinga, and Home oil companies of the Oil City area, which get their oil from the purple-shale member of the Upper Cretaceous. All the other samples were from wells that do not penetrate lower than the top of the Tejon (Eocene). The Cretaceous oil is greenish or brownish in color, of light gravity, and contains paraffin, a high percentage of naphtha, and a very low percentage of asphaltum. The other oil of the district is distinctly an asphalt oil and is lacking in paraffin. It is therefore evident that there are two distinct oils in the Coalinga district, to which different ages and origins are to be ascribed.

The asphalt oil affords by far the most abundant supply of the district and is believed to have its source in the shales forming the upper member of the Tejon, which are petroliferous throughout the district. This oil is obtained by the wells from the Miocene beds, which are petroleum-bearing wherever they overlie the shales of the Tejon. Wherever they overlie some older formation, however, their relative productivity varies inversely with the distance from those shales.

If we were to suppose that the oils of this district had some deeper-seated origin and that the shales of the upper Chico and of the Tejon had acted merely as channels of migration for the oil from below we would expect to find the shales of the subjacent Knoxville-Chico (Cretaceous) also acting as channels of migration, for they are apparently of proper consistency (clayey shale) for migration by diffusion. We would also expect to find them charged with oil, their interbedded sandstones productive, and the Miocene formations overlying them containing at least as much oil as, if not more than, the same formations overlying the Tejon. But these postulated conditions concerning the Knoxville-Chico (Cretaceous) do not exist. In all that part of the district in which the purple shale, the uppermost member of the Knoxville-Chico, is not present the Cretaceous shales and sands have been examined carefully in outcrop, and wells have been drilled into them in several places, but no indications of petroleum were found. Beds of Miocene age do not occur in contact with the petroliferous member at the top of the Chico. Where Miocene (Vaqueros, Santa Margarita(?), Jacalitos, and Etchegoin) sands overlie the Cretaceous in a position analogous to that of the Miocene overlying the Tejon (Eocene) these sands yield oil only when situated comparatively near the Cretaceous-Eocene contact. This is most significant, indicating that the Cretacous did not yield the oil, but that, as would be expected, the oil, after passing from the Eocene into the Miocene, has migrated for a short distance along the strata of the Miocene out over Cretaceous beds. Further negative evidence pointing to the origin of the oil in the upper members of the Chico and the Tejon is presented by the fact that there are no faults of consequence within the productive area along which migration from depths could have taken place.

CONTOUR MAP OF THE COALINGA FIELD.

EXPLANATION.

The contour map of the Coalinga field (Pl. XV) shows the topography, geologic structure, boundaries of the more important geologic formations, and certain details of culture, such as towns, section lines, property lines, a few roads, and oil wells. The structure in the pro-

ductive territory is indicated by contours showing the distance above (marked +) or below (marked −) sea level of the base of the Big Blue or top of zone B in the Eastside field, and of the top of zone B in the Westside field. The contour interval is 100 feet. By means of this map the direction and amount of dip of the strata in the oil-bearing formation may be calculated for any point in the field, and the depth to the various productive sands or zones may be approximated for most parts of the territory. (See also figs. 7, 8; Pls. XVI, XIX, XX, XXI.)

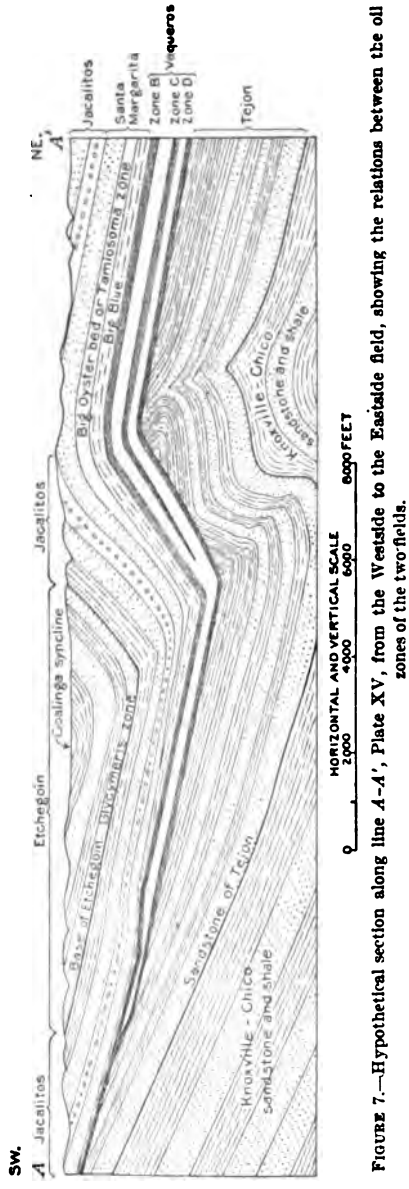


FIGURE 7.—Hypothetical section along line A-A', Plate XV, from the Westside to the Eastside field, showing the relations between the oil zones of the two fields.

USE OF THE MAP.

Suppose it is desired to find the probable depth below the surface of the first productive sand at the middle of the north line of the SE. ¼ sec. 24, T. 20 S., R. 14 E. Examination of the map will show that this point lies approximately on the underground contour line marked "−500;" that is, the top of zone B is about 500 feet below sea level here.

A close approximation of the elevation of the point may be had by looking up the elevation for the nearest derrick (see list, p. 248), which happens to be Claremont No. 4, elevation 792 feet, and calculating the difference in elevation, say 22 feet lower, either by the eye or with an aneroid barometer. The distance from the surface to the top of zone B is therefore 500 feet plus 770 feet, or approximately 1,270 feet; and as zone B is the uppermost productive zone for this part of the field that distance is the one desired.

Again, suppose it is desired to find the depth to the main commercially productive zone at the center of sec. 5, T. 20 S., R. 15 E.

Proceeding as before, it is found that the depth of the uppermost zone is about 1,460 feet below sea level and that the elevation of the

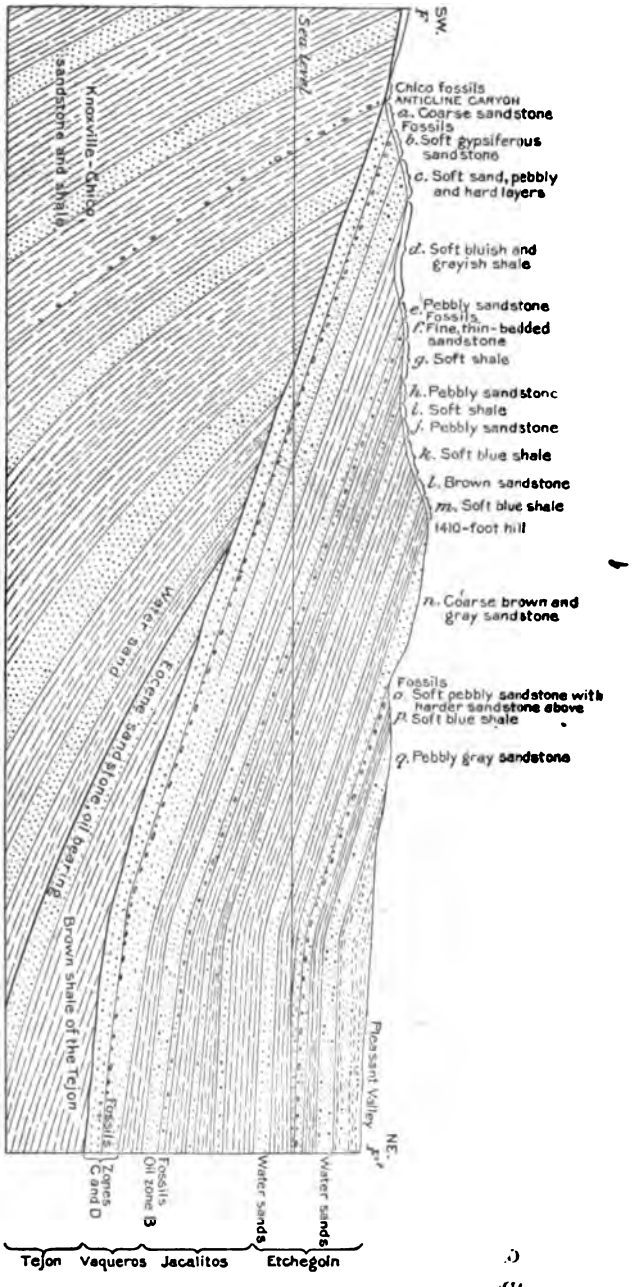


FIGURE 8.—Hypothetical section along line *F-F'*, Plate XV, from Anticline Canyon to California Oil and Gas Company's well No. 1. Based on surface traverse and well logs. (See pp. 219-220 for explanation.)

point is about 950 feet above sea level, or that the top of the upper most zone is about 2,410 feet below the surface. It will be found,

however, by reading over the text referring to this part of the field that the most productive zone is zone D, which lies from 300 to 450 feet below the top of the upper productive zone (zone B) in this region. Therefore the distance to the top of the commercially productive zone will be 2,410 feet plus 300 to 450 feet, or between 2,710 and 2,860 feet.

Suppose it is desired to find the dip of the beds in the NW. ¼ sec. 23, T. 19 S., R. 15 E. An examination of the contours shows that the beds are dipping a little east of southeast (or striking a little north of northeast), and that the dip is about 850 feet for half a mile or about 32.5 feet per hundred feet at right angles to the strike. The south and east components of this dip may be calculated by measuring in these directions instead of directly down the dip of the beds, which is always at right angles to the direction taken by the contours.

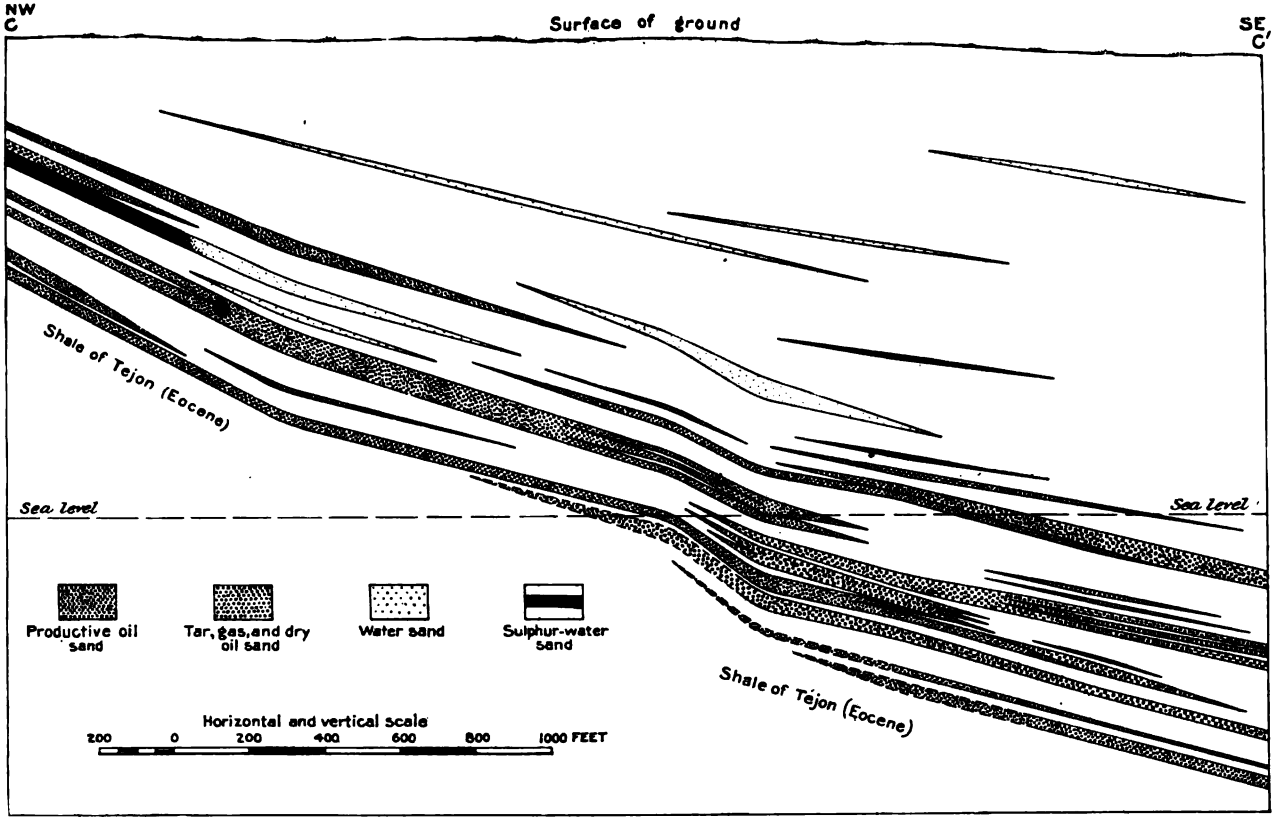
BASIS OF THE CONTOUR MAP.

The section lines and other culture marks were determined by E. P. Davis, of the United States Geological Survey. The log of nearly every well in the field either finished or sunk any considerable distance on October 15, 1909, was used in the determination of the underground structure and the compilation of the data concerning the oil zones. All the obtainable surface evidence of dip, strike, and occurrence of petroleum was also used in the preparation of this map. Where the surface and the well-log evidence were at variance the latter was usually followed. In unsymmetrical features like the Coalinga anticline and Coalinga syncline the plane of the axis of the fold is not vertical, and therefore the anticline as indicated by the contours showing the underground position of certain zones does not lie directly under the trace of the same anticline or syncline on the surface.

DIFFICULTIES OF PREPARATION AND DEGREE OF ACCURACY.

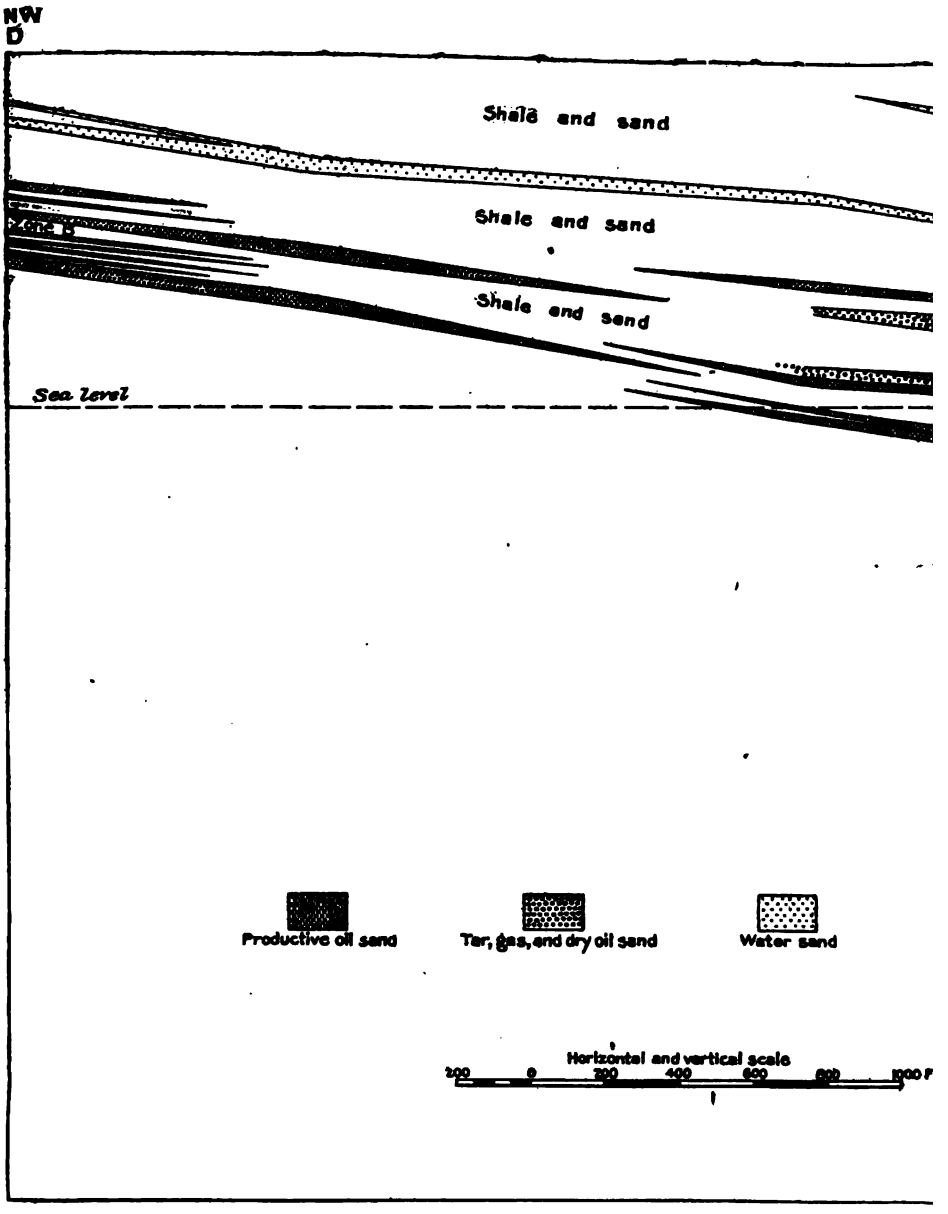
After all the logs had been carefully plotted on a uniform scale it was found that the greatest obstacle to overcome in the preparation of the contour map was the difficulty of correlating the strata from one well to another and from one part of the field to another. The difficulties of such correlations are doubtless familiar to anyone who has tried to work out the underground structure of any of the California fields. It must be said, however, that the structure in the Coalinga district is more regular and the conditions more favorable for a successful study and mapping of the underground geology than they are in any of the other California fields so far examined by the senior author, not excepting the Santa Maria field, which was studied in 1906 and of which an underground contour map was prepared.[a]

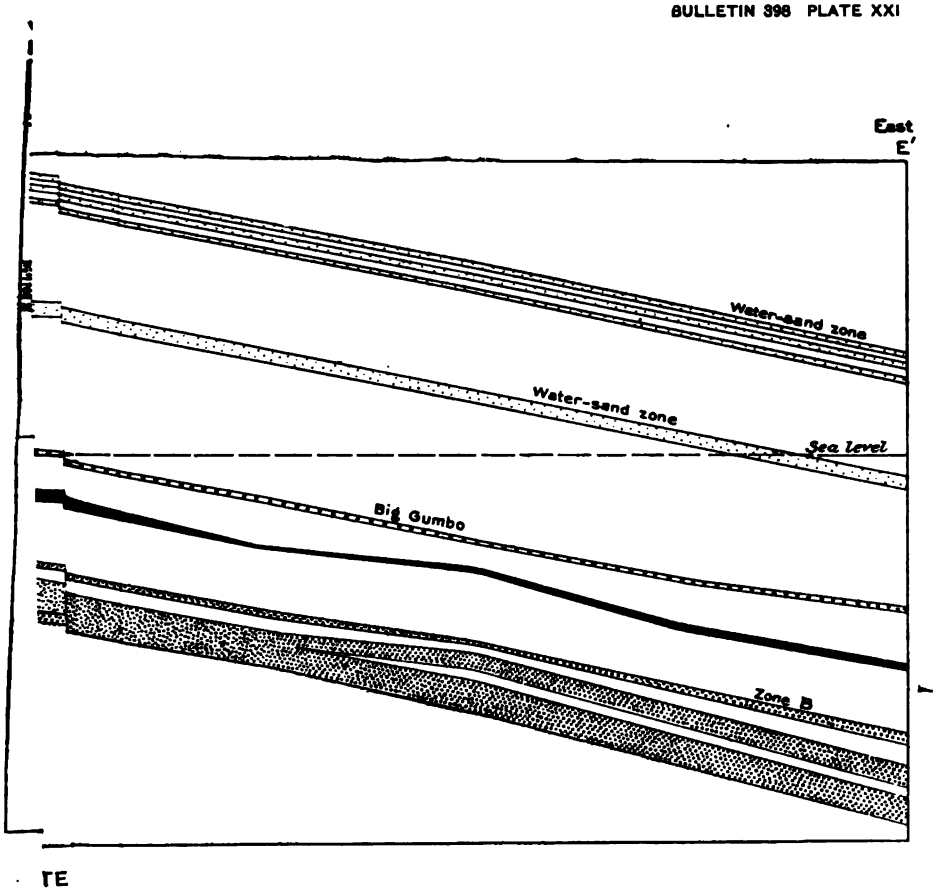
[a] Bull. U. S. Geol. Survey No. 322, Pl. X.



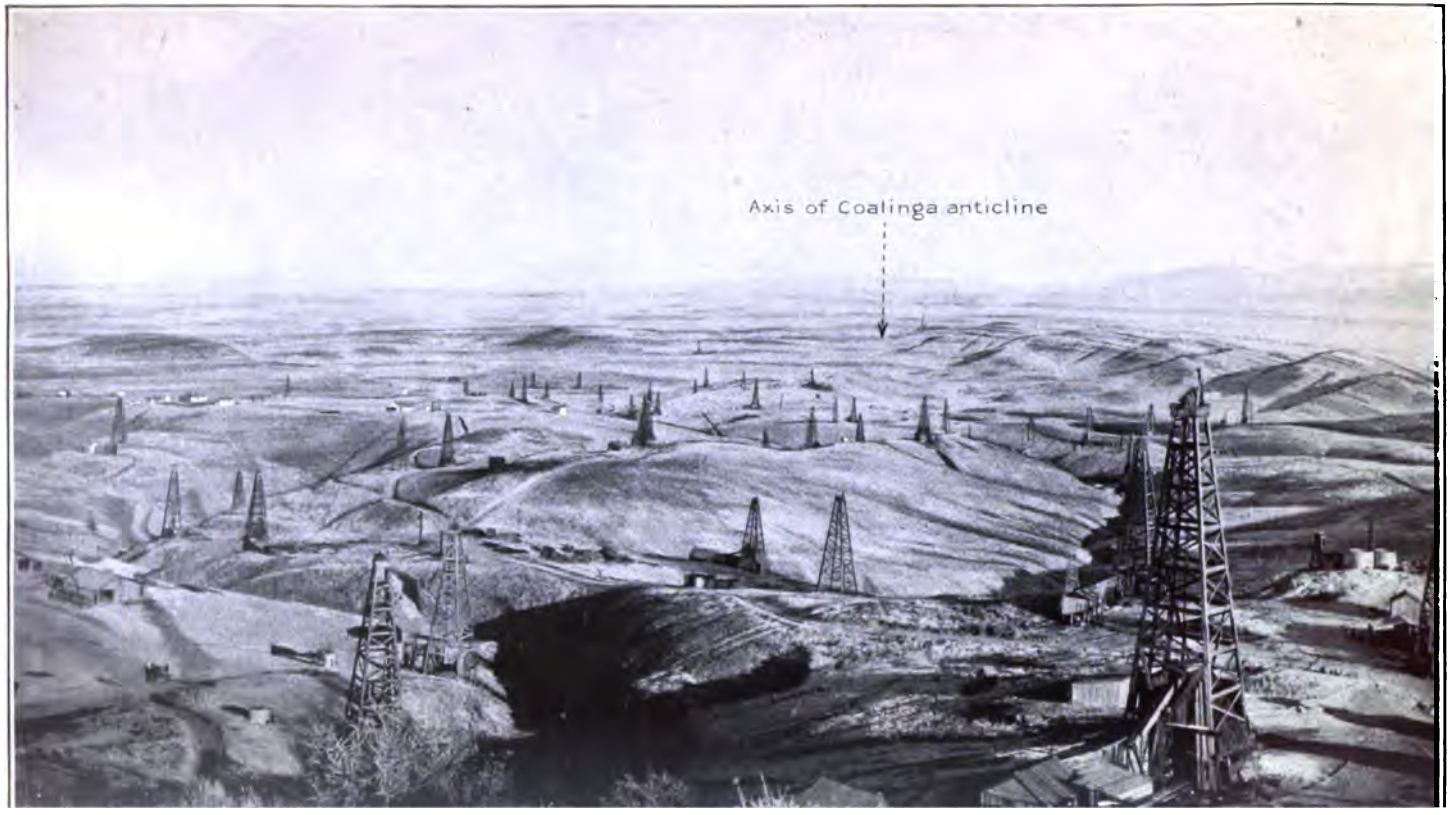
HYPOTHETICAL SECTION ALONG LINE C-C' ON CONTOUR MAP, PLATE XV.

U. S. GEOLOGICAL SURVEY




East
E'
Water-sand zone
Water-sand zone
Sea level
Big Gumbo
Zone B

REGULARLY DIPPING BEDS OF SANTA MARGARITA (?) AND JACALITOS FORMATIONS ON NORTHEAST FLANK OF COALINGA ANTICLINE IN EASTSIDE FIELD.


Axis of Coalinga anticline

The effort has been made to delineate on the present map all the details of structure consistent with the use of the well logs as confidential information, and to supplement these details by showing for the untested areas what seem to be most probably the conditions of underground structure. Within the untested areas the underground contours are of course only hypothetical and are shown by broken lines.

Regarding the degree of accuracy, it may be stated that the exact elevations of practically all the wells in the field were used in the preparation of the map. The well logs are assumed to be accurate to the usual degree—that is, ordinarily to the length of one "screw," or about 5 feet. The factor of error for the developed territory is therefore small, but necessarily increases with the distance away from the drilled ground. Future development will add much to our knowledge of this field and will show the inaccuracies of the contouring as here presented, but it is hoped that the benefits which may accrue to the operators from a knowledge of the general structure of the field will compensate in a measure for the errors in detail which are to be expected in a map based on incomplete data.

DETAILS OF THE PRODUCTIVE AREAS.

OIL CITY FIELD.

LOCATION.

The Oil City field occupies the southern part of sec. 17 and the northern part of sec. 20, T. 19 S., R. 15 E. The conditions in the territory immediately south of Oil City, in the southern part of section 20, which has been tested but found to be poorly productive, will also be discussed here with the Oil City field. The Coalinga Oil Company and the Home Oil Company are now the only producers in the Oil City field.

GEOLOGY AND STRUCTURE.

The Oil City field is situated along the east side of the belt of shale and interbedded sands of the uppermost member of the Knoxville-Chico (Cretaceous), which has been often referred to as the purple-shale member, the oil being obtained chiefly from the sandy zones in the lower portion. The proved productive ground occupies the same general relation to the plunging Coalinga anticline as the productive territory farther southeast in section 28—that is, it is on the more gently inclined or northeastern flank of the fold. Surface dips of 50° to 90° and even dips overturned past the vertical occur throughout the area along the southwestern limb of the anticline, while a surface dip of 32° is the maximum for the northeastern limb. The well logs indicate a relatively constant dip of about 26°

(42 to 44 feet per hundred feet) southeastward down the axis of the anticline and relatively a somewhat steeper dip in the beds immediately north of it in the productive territory.

GEOLOGY OF THE WELLS.

The wells start either in the upper portion of the purple-shale member of the Cretaceous or in the lower portion of the Tejon (Eocene) and continue in brown, black, and blue shale to the bottoms, except where they pass through the oil sand. From one to three sands are penetrated. The first is from 4 to 15 feet thick and yields the lightest oil, which is amber-colored and which runs as high as 48° Baumé in gravity; gas is also reported from the first sand in other wells, and in still others it is dry. The second and third sands comprise a zone 60 to 100 feet thick, which is petroliferous throughout almost its entire distance in some of the wells, while in others the two sands are separated, the upper usually running from 15 to 20 feet thick and the lower from 40 to 60 feet.

A section of the second and third sands in the productive area is as follows:

Section of second and third oil sands, Oil City area.

	Feet.
Hard sand	4
Soft pay sand	15
Very hard sand	6
Alternating hard and pay sands	47
	72

All the sands are comparatively fine grained. The oil usually comes from the softer sands and the lower sand is generally the most productive, although it is entirely unproductive in some of the wells. The wells vary in depth from 300 feet up to nearly 1,700 feet, and the productive zone is reached at depths varying from about 250 to 1,500 feet. The southern part of sec. 20, T. 19 S., R. 15 E., has been pretty thoroughly tested and, though most of the wells have yielded more or less oil, they were not deemed profitable enough to warrant continuous operation. The following log of a typical well in the abandoned territory will show the general character of the Tejon formation for this part of the area:

Log of Phoenix Oil Company's well No. 3, in the SE. ¼ sec. 20, T. 19 S., R. 15 E.[a]

	Feet.
Pink shale	300
Sand with water	330
Dark-colored shale	420
Sand with sulphur water and oil	440
Dark-colored shale	500
White clay shale	520

[a] Watts, W. L., Oil and gas yielding formations of California; Bull. California State Min. Bur. No. 19, 1900, p. 140.

	Feet.
Oil sand	535
Shale	540
White shale	560
Oil sand	575

This well is said to have yielded 50 to 60 barrels of black heavy oil (10° to 12° B.) for a short time. This low gravity is accounted for by the disturbed condition of the strata which the well penetrated, it being located directly on the anticline and just above an oil seepage in the canyon.

Well No. 2 of the Phoenix Oil Company, located about 300 feet west of No. 3, struck the sand at a less depth but yielded less oil. No. 1 went to 1,300 feet, but being southwest of the anticline never produced. The log given above and the conditions described are characteristic of most of the test wells put down in this area. The following are the companies that have operated here south of Oil City:

Blue Goose Oil Company, E. ½ NE. ¼ sec. 20; well No. 1, depth, 2,200 feet, through brown and blue shale; no oil, but much water; abandoned.

California Oil and Gas Company, SE. ¼ sec. 19; well No. 1, formation principally shale; abandoned. Same company has a well in the SW. ¼ sec. 20, also abandoned.

Crescent Oil Company, SE. ¼ sec. 20; well No. 1, depth, 900 feet; little oil at 770 feet; gravity, 11° Baumé.

Mutual Oil Company, SE. ¼ sec. 20; well No. 1, depth, 1,800 feet; abandoned.

New York Oil Company, SW. ¼ sec. 20. Well No. 1, depth, 1,000 feet, all in brown shale; no oil; abandoned. Well No. 2, depth, 2,200 feet, in brown shale with few hard sand layers; no oil; abandoned.

Selma Oil Company, SE. ¼ sec. 20; well No. 1, depth, 1,742 feet; little oil sand.

Zenith Oil Company, SE. ¼ sec. 20. Well No. 1, depth, 2,380 feet. A little oil sand at 1,735 feet yielded 10 barrels a day of amber-colored oil, 38° to 42° Baumé gravity. Later it was drilled deeper and struck a large quantity of salt water which rose within 300 feet of the top of the hole. The oil sand in this well is probably the same as the uppermost sand in the productive Oil City area. The occurrence of salt water below this is suggestive of "bottom" or "edge" water for the lower sands of the Chico oil zone. Well No. 2, same as Selma No. 1 (?).

PRODUCT.

The production of the wells in the Oil City area varies from the initial output of one well said to have been 700 barrels of oil per day for a short time to the daily run of certain others, which now will average not more than 4 barrels per day. In several wells the oil is said to have flowed over the top of the derrick when the oil sand was first penetrated, as a result of gas pressure, which soon subsided. All the wells have to be pumped after a short initial period of spontaneous flow. The average daily production at present is about 20 barrels per well. The average normal rate of decrease per well for the field, disregarding the rapid decrease from the initial production, has been between 15 and 20 per cent per year since 1900. The productiveness of the wells increases down the nose of the anticline toward the south-

east, especially near the axis of the flexure. This is shown by the fact that wells No. 3 of the Home Oil Company (the original Blue Goose well) and No. 7 of the Coalinga Oil Company have been among the best producers in the group.

The gravity of the oil varies from as high as 42° to 48° Baumé, of which grades there are only small amounts of oil, said to come from the uppermost sand in some of the wells (5 gallons of 48° oil from one well), to the usual run, which tests between 33° and 34° Baumé. There is apparently little variation in gravity between the wells up or down the dip or along the strike. The oil is greenish to brownish in color and shows little viscosity. It is a paraffin oil and very different from the oil that occurs in the oil zones in the Miocene.

EASTSIDE FIELD.

PEERLESS—BRITISH CONSOLIDATED—T. C. AREA.

LOCATION.

This area comprises that part of the Eastside field which includes the northeastern portion of section 21 and the northern part of sections 22, 23, and 24, extending to the line between Tps. 18 and 19 S. at the north end of the area mapped. The companies operating in this area are the Coalinga Peerless, Camwell, Good Luck, British Consolidated (formerly California Diamond), Lorene, T. C., William Graham, Imperial, Bowling Green, and California Oilfields (Limited).

GEOLOGY OF THE WELLS.

All the wells in this area start down either in the Santa Margarita (?) (middle Miocene) or the Jacalitos (upper Miocene) formation between the top of the Big Blue and the base of the Etchegoin. They all penetrate to, and some of them entirely through, the Vaqueros (lower Miocene) formation, which includes the oil-bearing zones, B, C, and D, of this part of the field. The variation in the beds penetrated is rapid, as the logs indicate, and it is seldom possible to trace a single stratum except the Big Blue more than one-eighth or one-fourth mile.

The map (Pl. XV) indicates by contours the distance of the base of the Big Blue above or below sea level. The Big Blue varies in thickness in the wells, if the distance penetrated be counted as equivalent to the thickness, from about 260 feet at the western edge of the area to over 350 feet in deeper wells toward the east. In fact, one of the deep wells disclosed a continuous shale formation for about 640 feet, but it is not believed that this entire thickness is included in the Big Blue farther west. In the region of section 2 the Big Blue and its included or equivalent red beds and sandy layers are penetrated for about 600 feet in the wells. One of the unique characteristics of the

Big Blue for this area and also for nearly all of the Eastside field consists of the red-shale layers which are at various points interbedded with the blue variety. These red shales are well shown in outcrop in secs. 3 and 10, T. 19 S., R. 15 E., where, owing to their peculiar tints, they may be seen for a distance of several miles. The red shale consists almost entirely of comminuted serpentine, which is naturally green but is turned red by the oxidation of the iron, of which serpentine contains a relatively high percentage. The red shale appears prominently on the sumps, where it forms brilliant coatings as the material is dumped from the bailers.

Water sands from 20 to 175 feet thick are found just above the Big Blue from the western part of the NW. ¼ sec. 22 eastward to the deepest wells. Lenses of water sand are also reported in the Big Blue from the middle of section 14 eastward.

Seashells are another characteristic of the logs of this part of the area. They occur from about 120 feet above the Big Blue in the Peerless area to 230 feet above it in the wells in section 12. Some of the deeper wells also show a layer of seashells about 530 feet above the Big Blue.

A more or less persistent zone of sulphur sands lie from 20 to 180 feet above the first productive zone, zone B, but is not reported in all the wells. In the region of section 2 sulphur water is usually encountered within 50 feet below the bottom of the Big Blue. Sulphur water also occurs below the productive sands in two of the wells only, while certain of the Peerless wells are said to yield no water whatever. These facts clearly indicate that the water occurs in more or less isolated lenses of sand, similar, in a general way, to the lenses carrying the oil.

Between the base of the Big Blue and the second productive oil zone (zone C) there is about 350 feet of dry sand, shells, and, just above the oil sand, some blue or brown clay or shale layers, the last sometimes carrying oyster shells. These last are often interbedded with dry or poorly saturated oil sands (zone B, in part). The thickness of the strata intervening between the Big Blue and the top of zone C reaches 450 feet in the deeper wells farther east down the dip.

Very little regularity exists in the oil zones, as is shown by the well logs. The productive beds (zones C and D) consist of alternating coarse sands, fine gravels, blue and brown shale, and shells, with coarse gravel at the base of zone D. The productive measures are usually about 225 feet through—that is, from the top of the first productive sand to the brown shale of the Tejon (Eocene)—and, though they comprise both zones C and D, a separation of the two is not possible in many of the wells. The total thickness in the wells from the base of the Big Blue to the brown shale of the Tejon is a little over 600 feet. Toward the northern part of the area under discussion the strata

below the base of the Big Blue thin to about 500 feet in the wells, only the lower 150 feet of this being productive.

Various names have been applied to certain individual sands that have been traced for short distances throughout this area. Among these is the Sauer Dough sand, which is the uppermost sand in some of the wells along the western edge of section 22. It is usually about 10 feet thick. About 40 feet below the Sauer Dough is a 40-foot sand known as the Pulaski sand. A careful comparison of the logs in the area shows that these two sands, and others also to which local names have been given, are not traceable for any great distance, although the names have been applied to various strata in wells over other parts of the Eastside field.

PRODUCT.

Nearly all the wells in this area have been drilled since 1904, so that data concerning decrease in production are rather meager. The production of the wells varies from about 25 to something like 700 barrels, the production increasing down the dip, other things being equal. The T. C. well in section 2 is said to have had an initial production of 400 barrels a day, but the yield has now fallen to 100 or 150 barrels a day, which is believed to be a fair initial average of what would be encountered over most of the area in properly handled wells 1,500 feet or more in depth. The average production for the wells in the area is about 125 barrels per day. The yield depends largely on the handling of the well, for holes going down under practically the same conditions give quite different results under various managements. One well which had an initial production of 200 barrels now yields only 20 to 25 barrels per day. This decrease is probably due not entirely to natural causes but to a sanding up of the hole. The gravity of the product from this area varies from 18° to 24° B. So many sands are perforated that it is usually impossible to tell the gravity of the oil from any particular one. However, the uppermost important productive zone (top of zone C) in the area is believed to yield oil of between 20° and 21° B. gravity. The next sand, say about 80 feet below the first, yields oil of 24° B. gravity, or possibly slightly better, while the lowest sand (base of zone D) which rests directly on the shales of the Tejon formation produces oil of 18° or 20° B. gravity.

Some of the wells yield a little water with the oil, and it is claimed by some drillers that this water comes from the oil sands, but it is the belief of the writers that in nearly every instance the water has leaked in from the surrounding water sands and is not obtained directly from the oil sands. Relatively little sand is yielded by the wells after the initial period of production, but much trouble has been encountered in some of the deeper wells owing to the gas pressure forcing the sand in from the bottom. Gas accompanies the oil in all the wells and is

also encountered alone in isolated pockets, usually above the productive zones. Other conditions being the same the greater gas pressure occurs in the deeper wells.

TECHNOLOGY.

The best success in shutting off the water in this area has been in landing the casing in a blue shale just below the sulphur-sand zone. Surface waters are shut off above this with a larger casing, but the purity of the oil depends entirely upon the careful handling of the lower waters immediately overlying the oil sands.

STANDARD—CARIBOU—BRITISH CONSOLIDATED AREA.

LOCATION.

The area described in this section covers the northeastern portion of section 27, the southern part of sections 22, 23, and 24, all of sections 25 and 26, and the northern part of sections 35 and 36. The following companies operate in this area: California Oilfields (Limited), Standard, Caribou, Associated, Twenty-Two, Record, Pittsburg, Octave, Sauer Dough, Porter, British Consolidated, and Boston and California.

GEOLOGY OF THE WELLS.

The wells in this area, as in the area farther north, start down in the Santa Margarita (?) and Jacalitos (upper Miocene) sands and shales between the top of the Big Blue and the basal Etchegoin. In the area where sections 21, 22, 27, and 28 meet the Big Blue is about 220 feet thick in the wells, increasing toward the eastern limit of the productive territory to about 320 feet. Red shales are reported interbedded in the Big Blue in nearly all of the wells throughout the area. These red beds seem to thicken and become relatively more prominent in the deeper wells toward the east and north. Some white and light-blue shale layers also occur in the same zone, and in the western part of the area gray and brown dry sands are encountered above it. From a point a short distance west of the middle of the line separating sections 22 and 27 the same sands contain water at various distances above the shale.

All of the strata from the base of the Big Blue to the top of the Tejon (Eocene), embracing a distance in the wells of 620 to more than 800 feet, are more or less petroliferous throughout this area. Three oil zones may be defined within these limits. The first zone (zone B, the top of which is shown in Pl. XV) begins immediately at the base of the Big Blue and is from 100 to 180 feet thick. The greater thickness occurs in the deeper wells. In the western part of the area zone B consists of dry sands, dry oil sands, or poorly saturated oil or tar sands; farther east it is commercially productive

in some of the deeper wells but not in all. Where productive, as in the western part of section 26, the gravity of zone B oil is about 14° to 16° B. Below zone B and between it and zone C the strata are largely shale and dry sand.

The second and third zones (zones C and D) are closely related, the second being the uppermost important producer over most of the area. Zone C consists of medium-grained sand yielding light-gravity oil (24° B. or better), is about 100 feet thick, and begins about 400 to 480 feet below the base of the Big Blue. There are usually from one to four productive sands in this zone. The lowest productive zone (zone D) rests directly on the shale of the Tejon (Eocene), is very coarse, consisting of pebbly sand or fine gravel, and is usually the best producer as regards quantity, although the oil is of but 20° to 23° B. gravity.

Sulphur water overlies zone B in the area north of a line drawn south of Caribou Nos. 11 and 10. Fossil shells are reported at the base of the Big Blue in some of the wells, while in others, as in the region farther north, they occur about 450 feet above the base of the Big Blue. The seashells in some of the Caribou wells are found just above the oil sand and associated with it.

Water is now causing trouble in the region of the SE. ¼ sec. 22, T. 19 S., R. 15 E.; the source is believed to be sands occurring in the Vaqueros between zones B and D. Some of the operators lean to the belief that this water has been let into the sand by faulty handling of the wells; others believe that the water was originally in these sands, and to this theory the writers are inclined.

PRODUCT.

Most of the wells in this area also have been begun since 1904, so that figures for decrease in production are meager. All of the productive sands are perforated in many of the wells, so that it is often impossible to tell the production or gravity of any one sand. However, the general features of variation are known and will be indicated. The initial production in the wells varies from about 150 to 1,600 barrels per day. The average production at present is somewhere near 400 barrels. The best producers, as a rule, are among the deeper wells, although for one which is well up on the dip (SE. ¼ sec. 21) an initial yield of 1,500 to 1,600 barrels per day is reported. This well obtained 200 barrels per day from the upper sands, but was lowered into the deeper sands, where it made its phenomenal record. Besides the one mentioned, there are at least two other wells in the area that have produced more than 1,000 barrels a day. The average decrease in production for three years has varied from about 20 to 40 per cent, but some wells are said to have held out much better than this.

The gravity of oil in this area varies from 16° to about 24° Baumé. The heavy oil comes from the upper sands (zone B), which are usually more productive in the deeper wells. A well in the W. ½ sec. 26 is said to have yielded 600 barrels of 15° or 16° oil from zone B when first drilled. The middle zone (zone C) produces oil of about 24°, while the lower, coarser, but generally more productive sands (zone D) yield oil of 21° to 22° B.

Gas occurs in practically all of the wells. In some of them there is sulphur, but most of them yield a good gas free from this element. The influence of one well upon the gas pressure in another is often very marked. A certain well, for instance, dropped off more than 25 per cent in production when another well within 300 feet of it was brought in.

STANDARD—CALIFORNIA OILFIELDS (SEC. 27) AREA.

LOCATION.

This area includes the eastern part of section 28 and the western part of section 27, excluding the portion along the south line of section 27. The Standard and California Oilfields (Limited) are the only companies operating in this area.

GEOLOGY OF THE WELLS.

All of the wells start down in the Santa Margarita (?) (upper middle Miocene) and Jacalitos (upper Miocene) formations, above the top of the Big Blue and below the base of the Etchegoin, which usually include alternating sands and shales with occasional water sands. These water sands as a general rule are in the form of lenses and can seldom be traced in the wells for more than an eighth of a mile.

The Big Blue maintains a pretty uniform thickness of about 250 to 300 feet throughout practically the whole of this territory. In the wells along the middle of the line between sections 27 and 28 there is a fairly persistent stratum of water sand immediately overlying the Big Blue. There are other water sands above this lowest one in some of the wells, but none that can be traced far. An interesting stratum, encountered in the wells beginning in the vicinity of the California Oilfields, section 27, No. 20, and extending down into the northern part of section 34, is known as the St. Paul sand. It lies about 830 feet above the base of the Big Blue, or from about 150 to 600 feet below the surface. It is about 30 feet thick and hard, but is believed by some of the operators to be capable of yielding 50 barrels of oil per day, though as far as known it has never been thoroughly tested. This occurrence is rather puzzling, as there are no other oil sands within several hundred feet of it and the origin of its petroleum is difficult to explain.

The oil-bearing formation in the area under discussion extends from the base of the Big Blue for about 655 feet as measured in the wells

down to the top of the brown shale of the Tejon (Eocene). This distance between the base of the Big Blue and the brown shale is apparently regular over that part of the area which has been tested. The deepest wells have not penetrated the entire thickness of the oil sands, so that the exact thickness of the sands is not known for wells far down on the dip.

Three zones are recognizable in this series of productive beds. The first (zone B) occurs at the base of the Big Blue, is about 15 to 20 feet thick, and yields from 30 to 50 barrels of 21° B. oil in the shallower wells.

The second (zone C) is about 300 feet below the top of the Big Blue, has a thickness of 60 feet, and produces daily from 100 to over 1,000 barrels of 22° to 24° B. oil per well. A group of wells in the middle of the western part of section 27 and in the eastern part of section 28 produce oil of 25° to 31° B., the initial production of the wells varying from 125 to 1,900 barrels per day. The oil from zone C, in this local area of unusually light oil, is kept separate in most of the wells, but whether or not all of the yield from the big producers in this light-oil area comes from zone C is not known. The sands in this light-oil zone are finer grained than those in the zone above or the zone below.

The third oil zone (zone D) consists of coarse, pebbly sands and fine gravels and extends practically from the top of the brown shale of the Tejon upward for over 100 feet. Oil-bearing sands are found at practically all horizons in one well or another from the base of zone C to the top of zone D, so that a separation of the two is necessarily more or less arbitrary.

PRODUCT.

The wells in this area have all been drilled since 1902. The product of those wells deriving their supply from the upper sands (zone B) varies from 30 to 50 barrels per day of 21° B. oil. The middle zone (zone C) yields from 125 to 1,900 barrels per well per day, the gravity ranging from 24° to 31°. One well which had an initial production of 1,900 barrels per day in 1904 dropped to 1,300 barrels per day after one and one-half years. Several of the wells yield on an average 300 to 400 barrels per day, while another group averages but 125 barrels of 26° B. oil. The third zone (zone D) yields oil of 22° to 23° B. It is the best producer, as far as quantity goes, in this part of the field. The better gravity and greater production in this particular area are believed to be due to the position of the wells adjacent to the axis of the anticline, where the shales of the Tejon (Eocene), from which the oil is derived, are much more fractured and where, in consequence of this fracturing, the oil is permitted to migrate more easily and with less loss in quality into the overlying porous sands.

The concentration of the oil within the Tejon, before its emigration, was also doubtless accentuated along the anticline by the action of the water which is associated with or immediately underlies the oil sands.

The presence of the light oil in the finer sediments is believed to be due to the fact that the lighter hydrocarbons can escape more easily from coarser reservoirs than from fine-grained ones, so that, when once charged with the oil, the finer-grained sands allow it to maintain its original quality more perfectly than a coarse sand would. As would be expected, the production under the same pressure is considerably less in finer sediments than it is in coarse sands, but the length of productivity is consequently greater in the former than in the latter.

CALIFORNIA OILFIELDS (SEC. 34)—COALINGA-MOHAWK AREA.

LOCATION.

This area comprises the whole of secs. 34 and 35, T. 19 S., R. 15 E., and secs. 1, 2, 3, 4, 11, and 12, T. 20 S., R. 15 E. The California Oilfields (Limited), Kern Trading and Oil (Southern Pacific), W. K. Turner, Claremont, Southeastern, and Coalinga-Mohawk are the companies operating in this territory.

GEOLOGY OF THE WELLS.

As in the other areas described, the base of the Big Blue is the horizon shown by the contours on the accompanying map. The wells in the northern part of the area start down in the Jacalitos (upper Miocene) beds immediately underlying the base of the Etchegoin. Those south of the line marking the base of the Etchegoin start in the sands or clays of this formation. The Big Blue in the wells of this area varies from 250 feet in thickness in the northwestern portion to about 380 feet at the southwestern border. The peculiar red, green, and light-blue facies of the shale, which are characteristic of the Big Blue in the deeper wells farther north, are also to be found in the deep wells in this area, especially those farthest south. In the northwestern portion water sands appear to be interbedded at the base of the Big Blue, as are also some tar and dry oil sands with occasional gas pockets. There are also other water sands in the deeper wells, an especially persistent zone occupying a position about 600 to 800 feet above the base of the Big Blue in the wells in the southern part of the area. Some of the water in this zone is said to contain appreciable amounts of sulphur.

The St. Paul sand of the area last described also occurs in the northern part of this territory, where it is encountered in practically all the wells, but in none of them, so far as the writers are aware, has it ever been tested. Those wells which have been put down to the

brown shale of the Tejon (Eocene) indicate that the formation between the base of the Big Blue and this shale has practically the same thickness of 650 feet or thereabouts that it has in the region to the north. The whole of this distance is occupied by alternating sandstones and shales, which are more or less productive in the various wells. The relations between the various oil sands in this area are not well known, but it is believed that the sequence of zones, including B, C, and D, is similar to that in the area last described. A 10-foot oil sand carrying 17° B. oil occurs at the base of the Big Blue, this sand probably corresponding to the one which yields a 16° B. or heavier oil in section 26 and which has been correlated with zone B. One hundred feet below the Big Blue the second sand, possibly zone C, is penetrated, this being productive through about 20 to 25 feet. About 400 feet still farther down is the third zone (zone D), which is believed to rest upon the shales of the Tejon (Eocene). A thin layer of sulphur water is reported in some of the wells just above this third zone, but enough blue or brown shale intervenes to allow complete shutting off of the water before reaching the productive zone.

PRODUCT.

The wells in this area are only four or five years old, but since their inception they have maintained a reputation as the biggest producers in the field. The oil in these wells is usually accompanied by large quantities of gas under strong pressure. As an instance of their unusual productiveness, it is said that one well in the northern part of section 34 yielded about 7,000 barrels of oil in eighteen hours. The casing was practically all torn out by the ejection of this large amount of fluid from the hole. This well is now producing but 150 barrels per day, which indicates that the great production was due to the extremely high gas pressure. Another well near the center of the southern part of section 27 is said to have yielded 4,500 barrels of oil per day for some little time. This well is now believed to yield about 3,000 barrels per day. The gravity of the oil from these big producers is between 23° and 24° B.

Another well in the northern part of section 34 yielded on an average about 1,000 barrels per day for over ten months. Still others of these wells run from 600 to 800 barrels per day. The Coalinga-Mohawk well, which penetrates but half of the oil-bearing zone between the base of the Big Blue and the brown shale of the Tejon, is said to have produced at first at the rate of 150 to 200 barrels of 32° oil a day. One well, which yielded 26° B. oil as long as it flowed, now yields a mixture of 23° B. oil when it is pumped. This implies that the lighter oil is probably under the greater gas pressure, and when this pressure is removed the heavy oil either forces back the lighter fluid or allows only a small percentage of it to

enter the well. The lower zones (zones C and D) in one well are said to yield a stratum of 29° B. oil at the top, 22° B. in the middle, and 26° B. at the base, with an average of about 28° B.

STANDARD—STOCKHOLDERS AREA.

LOCATION.

This area comprises all of section 28 except the extreme eastern edge, which is described in a previous section (p. 201). The Standard and Stockholders oil companies are the only operators.

GEOLOGY OF THE WELLS.

The Big Blue in this territory varies from about 200 to 230 feet thick in the wells. A layer of water sand is found just above it in the eastern part of the area, and one or two lenses of water sand have been reported as occurring in the Big Blue itself. The oil strata extend intermittently from the base of the Big Blue for about 655 feet to the brown shale of the Tejon (Eocene). The first 400 feet of the productive measures consists of alternating gas sands, oil sands, dry sands, and tar sands interbedded with shales and clays and has been correlated with zone B, although it is believed to comprise not only the zone B of the areas toward the east but the strata to the top of zone C. In the northwestern part of the area this upper zone is more or less productive, some of the wells which produced from it alone yielding from 10 to 30 barrels per day of 20° B. oil.

One or two persistent layers of water sand occur from 50 to 100 feet above the base of zone B, or above the top of the second or light-oil zone, zone C. Enough blue or brown shale intervenes between this water sand and the productive beds below to permit shutting off the water. Big oyster shells are reported in some of the wells just above the second zone, these probably coming from the same layer as that yielding the oysters in the Vaqueros formation on the Laval grade. Zone C consists largely of fine sand from 20 to 60 feet thick and yields oil of about 21° to 22° B. gravity. The third zone, or zone D, consists of coarse sand to gravel and begins about 100 feet above the brown shale of the Tejon (Eocene). It is productive through its entire depth, and yields more than any other of the zones in this group of wells. The daily production varies from 40 to 300 barrels per well of 18° to 22° B. oil.

Toward the axis of the Coalinga anticline the strata are more or less irregular on account of the steep dips which are developed by this profound fold. The logs of the wells along the axis are irregular and indicate varying conditions in both the dip and the productiveness of the beds. Water is also more troublesome in these wells, owing, it is believed, to the disturbed conditions of the elsewhere impervious beds that surround the water sands. There is very little gas in the sands toward the western edge of this area.

PRODUCT.

The wells in the area under discussion are the oldest in the Coalinga district except those in the Oil City area, and many of them have produced continuously since their inception. The first zone (zone B) yields up to 30 barrels per day of 20° to 22° B. oil; the second (zone C) yields a somewhat lighter oil, from 21° to possibly 23° B., and the third (zone D) produces as high as 300 barrels of 18° to 22° oil. Some of the wells yield sand from the lower productive beds, and water is also mixed with the oil in some of the wells in the broken formation near the axis of the anticline. In none of the wells in this area is the water believed to come from the bottom of the oil zone.

WESTSIDE FIELD.

CALL—CONFIDENCE AREA.

LOCATION.

This area is in the southwest corner of T. 19 S., R. 15 E., and comprises the territory controlled by the following companies: The California Oilfields (Limited), Call, Keystone, Ajax, Ætna Petroleum, Commercial Petroleum, Maine State (formerly the Guthrey), Confidence, W. M. & M. (formerly California Diamond), Empire, American Petroleum, and Kern Trading and Oil. The wells are on the southeastward-dipping monocline of the Westside field at a point where the strike of the beds begins to bend from northeastward to eastward around the axis of the Coalinga syncline.

GEOLOGY OF THE WELLS.

All the wells start down in the soft shales, sandstones, or gravels of the basal Etchegoin, or in the upper Miocene beds immediately underlying this. Toward the western part of the area the wells apparently penetrate only through the upper Miocene formations. On the western side, that is, in the deeper wells of the Call, California Oilfields (Limited), and Commercial Petroleum, the wells apparently reach sands in the lower Miocene (zone D) that are lacking or have not been reached in the wells in the western part of the area.

Zone B, the depth of which below the surface is indicated by contours on the map (Pl. XV), will first be described. Toward the western part of the area it contains the productive sands and is found from about 650 to 1,050 feet below the surface. The oil in this zone is apparently under considerable gas pressure, as in nearly all of the wells, even the shallower ones, the oil rises a considerable distance in the casing when the sand is first penetrated. The sand in the shallower wells varies from 10 to 20 feet in thickness, thickening toward the northeast from the region of the Kern Trading and Oil

territory. The sand is medium grained to coarse and soft, and the wells producing from it yield large quantities of sand with the oil, especially at first. Some of the shallower wells have been known to flow when first brought in. Farther east, in the vicinity of the eastern Confidence wells and those of the Maine State or Guthrey leases, the zone is apparently irregular and some of the logs of the wells, although reporting a production from the horizon at which the sands are found farther up on the dip, do not mention the thickness of the sands within the zone. Guthrey No. 1, which was the biggest gusher of this part of the field, might be mentioned as an illustration of the irregularity. The behavior of this well was very unusual and the exact location of the sand producing the gas and oil which flowed so strongly at first is doubtful. Enough sand was ejected from this well to cover the derrick floor and the surrounding ground for over 6 feet in depth.

In the deeper wells zone B is apparently represented by two sands which are separated in some instances by a waxy clay. The total thickness of the sand in these wells runs as high as 50 feet. Still farther down the dip, or in the deepest wells in the area, zone B apparently becomes unproductive, although it yields evidences of gas and petroleum in small quantities. In one of the wells this zone was pumped for three weeks, but the operators concluded that there was water in it and abandoned their efforts.

About 200 to 300 feet above zone B is a zone of tar sands (zone A), which, as the name implies, are either dry or yield oil of heavy gravity. These sands vary in number and thickness from well to well, although the zone as a whole is fairly persistent over the entire area. Sulphur water occurs within zone A, usually at the base of the first tar sand, and at some of the wells it is found at two horizons within the zone. The thickness of the tar sand varies from a minimum of 10 feet in some of the moderately deep wells to nearly 100 feet or possibly more in those farthest up on the dip. Thicknesses also occasionally approach 100 feet in the deep-well area.

About 200 feet above the zone of the tar sands (zone A) is a very persistent stratum of water. This water is mineralized in all the wells and in some shows traces of sulphur. Above this water zone are usually one or two other water sands, the first being only about 5 to 10 feet thick, but yielding considerable water. The second is less important and is apparently lacking in many of the wells.

In the deeper wells toward the eastern part of the area the most productive sands apparently lie below zone B and are believed to be in part the equivalents of the lower Miocene sands (zones C and D) which are the productive sands of the Eastside field. The exact relations of these zone D sands to the overlying ones are perplexing, but it is believed that zone D does not extend westward past the middle

of the area under discussion, although to the knowledge of the writers no well has yet been put down which passes entirely through the strata overlying the Tejon (Eocene) in this part of the field. Some of the wells have reached what they call the black or brown shale, but it seems likely that these brown shales may be simply petroliferous shales intercalated in the sands of the Vaqueros (lower Miocene). This lower Miocene sand zone (zone D) lies from 100 to 300 feet below zone B. Productive lenses are found at two or three points throughout the zone, but no continuous oil sands have been definitely traced between the wells.

Taken as a whole, the logs present the following features in passing downward from the surface: First the incoherent soil and gravel, then a thick series of dry gravels, sands, and shale or clay, with occasional hard sandstone shells. The first water is encountered usually between 240 and 500 feet. From this downward two and sometimes three other waters are penetrated before the tar-sand zone (zone A) is reached. The zone of the lower water sand or sands is often marked by numerous hard sand shells. After passing through zone A, which varies from a few feet to over 300 feet in thickness, a 200-foot zone of blue shale is encountered. Below this lies zone B, which is characterized by medium-grained to pebbly sands, brown shales, and several well-defined shells. The shallower wells usually stop at the base of this zone, but the deeper ones penetrate some shale and sands from the bottom of zone B to the top of the third zone, which includes zones C and D and is usually characterized by hard shells and medium-grained sands.

PRODUCT.

The production of the wells in this area varies from an initial output of 20 to 50 barrels in the shallower wells to 3,000 or 4,000 barrels in some of the deeper ones, such as Guthrey No. 1, which was a pronounced gusher when first brought in. The daily average for these wells runs somewhere between 100 and 200 barrels, but some of them average as high as 300 to 350 barrels over long periods.

The gravity of the oil runs from 14° to nearly 20°, the average for the shallower wells being about 16° and for the deeper wells about 18°. The best oil apparently comes from the middle zone (zone B), which is believed to correspond in a general way with the light-oil sands farther south in the Westside field.

MERCANTILE CRUDE—S. W. & B. AREA.

LOCATION.

This area comprises the southern part of the Kern Trading and Oil, Confidence, Coalinga Aztec, and E. W. Risley leases in sec. 31, T. 19 S., R. 15 E.; the Fresno-San Francisco and the northern parts of

the Cypress, Pennsylvania-Coalinga, and American Petroleum properties in the northeastern part of sec. 1, T. 20 S., R. 14 E.; and the Mercantile Crude, York-Coalinga, S. W. & B., New San Francisco Crude, and the northern half of Esperanza in sec. 6, T. 20 S., R. 15 E. The wells are on the southeastward-sloping monocline which dominates the structure of the whole Westside field.

GEOLOGY OF THE WELLS.

The wells in this area all start down in the basal Etchegoin (upper Miocene) clays, sands, gravels, etc., or in the Jacalitos (upper Miocene) beds immediately underlying these. Three more or less well-defined petroliferous zones are developed in this area. The top of the principal productive zone (zone B) is shown by contours upon the accompanying map (Pl. XV). A description of this zone will first be given. In the wells high up on the dip the character of the sand in zone B is coarse, and it usually contains pebbles the size of the thumb or sometimes even larger. Both immediately above and below the most productive part of the zone are sands in which the oil is heavier than that in the most productive part. The reason for this difference in gravity between sands so close together is not at present known, but it may be due, in part at least, to difference in grain of the sands. Farther down the dip the sand is somewhat thicker, but is still coarse, and in some of the wells contains shark's teeth. The coarseness of the sand and the gas pressure are conducive to good productions, and it is not unusual for wells at first to obtain as high as 300 or 400 barrels a day from this one sand. In the deeper wells the zone apparently contains but one sand, which is in most places underlain by a more or less persistent hard sandstone shell. The gravity of the oil in zone B runs about 17° B. and is apparently constant throughout the area. From 50 to 100 feet above zone B is a 100 to 200 foot zone (zone A) of tar sands similar to those encountered in the wells toward the north. This tar zone is thickest in the northwestern part of the area, and there it consists of one to three dry oil sands or tar sands which sometimes contain heavy oil and occasionally water associated with the oil. Eastward, or down the dip, the tar sand decreases rapidly in thickness, until in the deepest wells in the area the tar zone is represented by but one or two sands which never attain more than 10 or 20 feet in thickness. Immediately overlying zone A is a persistent stratum of sulphur water, which is encountered in practically all of the wells in this area and is known in general under the name "big sulphur," or "main sulphur." Beneath this sulphur water in most of the wells is a hard sand shell, which is apparently more or less persistent

throughout the area. Still another sulphur water is encountered a little above the lower one in some of the wells, but does not appear to be as persistent as the "main sulphur."

Below zone B in the deeper wells is still a third petroliferous zone (zone D), which may correspond in part to the lowest zone in the area immediately north. It is penetrated by but two or three wells and its productiveness is more or less uncertain. In one log this lower sand is mentioned as brown shale, although the same log shows that the casing was perforated at this point, thus indicating that the formation was oil bearing.

The water sands in the area are usually three or four in number, the uppermost being encountered at depths of 145 to about 375 feet. The first sand is apparently not so productive as the second, which yields plenty of water in many of the wells. Below the second sand is a third, and sometimes even a fourth, before the sulphur sand, immediately overlying the tar zone, is encountered.

Typical well log in Mercantile Crude-S. W. & B. area.

	Feet.
Surface soil and incoherent sand and gravel, followed by harder shales, sandstone, and gravels	200
First water sand	5–20
Shale	50+
Second water sand.	
Shale, sometimes containing one or more water sands	300
Gravel, more or less persistent, apparently carrying water in several of the wells, especially those nearest the outcrop.	
Shale	100+
"Main sulphur" water.	

The depths of the wells in this area vary from about 1,000 feet to over 1,700 feet.

PRODUCT.

The production varies from 12 barrels in the wells farthest west to about 400 barrels in the deeper and more productive ones. Large quantities of sand usually accompany the oil, especially in those wells high up on the dip, and even in some of those which penetrate the sand at much greater depth. The gravity of the oil varies from 13° to 17½° B., the average for the area probably being about 16°.

ZIER—PORTER & SCRIBNER M., K. & T. AREA

LOCATION.

This area comprises the southern part of sec. 1, T. 20 S., R. 14 E., the southern part of the American Petroleum and Esperanza properties, sec. 6, T. 20 S., R. 15 E., and the region of sec. 12, T. 20 S., R. 14 E., and secs. 7 and 8, T. 20 S., R. 15 E. The companies operating in

this area are the Zier, Ward, Seneca, Cypress, Pennsylvania-Coalinga, Esperanza, Shawmut, Section Seven, Coalinga Pacific, Arica (formerly Porter & Scribner), Brix & Buntin (B. & B.), Spinks, Coalinga Unity, St. Clair, Pilot, New Era, British Consolidated (formerly California and New York), Kern Trading and Oil (Southern Pacific), Coalinga National, Coalinga California, J. J. Cartner, American Petroleum (section 18), Nevada Petroleum (section 18), and M., K. & T. The wells are located on the flanks of the southeastward-dipping monocline which governs the structure in the Westside field.

GEOLOGY OF THE WELLS.

The wells start down in the basal Etchegoin or the soft Jacalitos beds immediately underlying this formation. Zone B, the one shown in contour on the map (Pl. XV), is at present the most important zone in this part of the field and yields the greater part of the production. In the western part of the area it varies from alternating sands and shales to a single bed of coarse sand 25 feet thick. The gravity of the oil from the zone in this part of the area varies from 13° to 14° B. Farther east and lower down on the dip the gravity of the product from zone B is considerably higher, ranging from 17° to 18° B. The beds yielding this lighter oil may possibly not be continuous with those farther west, which produce the oil of 14° B. gravity. On the contrary, the sands yielding the latter may possibly be represented in the eastern part of the area by the sands yielding 14° B. oil which immediately underlie the 17° B. oil sand. The 17° B. oil sand is not fine grained, but is fairly coarse, and in many of the wells contains shark's teeth, as it does in the area farther north. The zone, as indicated by logs, varies in thickness from 7 to 60 feet in the central part of the area. The production from a single sand in this zone ranges from 40 or 50 barrels up to the daily maximum of about 200 barrels per well. The light-oil sand appears to be missing in some of the wells, according to their logs, but it is believed that the formation is represented in the well but was overlooked by the driller while the hole was full of water. In the deeper wells, toward the eastern end of the area, zone B maintains the characteristics just described, varying in thickness from 8 to 30 feet, apparently being mixed with some shale in the thicker portion.

As in the areas farther north, zone B thickens rapidly toward the east until in the region of sec. 8, T. 20 S., R. 15 E., indications of petroleum are found throughout a vertical distance of over 1,100 feet. Here zone B is believed to be represented by what is known as the third or light-oil sand of the M., K. & T. wells, which lies several hundred feet above the most productive sands in those holes, is medium grained, nearly 100 feet thick, and is said to yield 22° B. oil.

If zone B is continuous, wells between the Porter & Scribner and the M., K. & T. leases ought to show a gradation in gravity from 17° or 18° B. in the former to 22° B. in the latter, which is much farther down the dip. This decrease in specific gravity (increase in degrees Baumé) down the dip agrees with the mode of variation found in most instances in the other California fields examined by the writers.

The same tar-sand zone (zone A) is encountered above zone B in this area, as is found in the same portion throughout most of the remainder of the Westside field. It varies in thickness from 20 or 30 feet to over 100 feet, being exceedingly irregular as reported in the well logs, although it is on the whole believed to be thicker down the dip toward the east. The tar sands are usually intercalated with shale and are often dry, but in some wells yield a small production of heavy oil of about 14° B. gravity or heavier. Prominent sandstone shells are usually associated with the sands and shales of this zone, some of these shells being traceable from well to well, and one in particular, of considerable importance, has been called the "big shell."

Below zone B and closely associated with it is a zone of 14° or 15° B. oil. This zone (zone D) has been penetrated in some of the wells for over 300 feet and consists of alternating sands and blue and brown shales, the brown shales usually predominating. It is barely possible that this lowest shale in the deepest wells is Tejon (Eocene), but no proof is available. Zone D is probably equivalent in part to the lower Miocene sand of the Lucile well and the wells on the Eastside field. In the deepest wells, which obtain most of their oil from zone D, that zone is always more productive than zone B.

Three or more water sands are usually encountered in the wells in this area. In the shallower wells and even in some of the deeper ones the water sand is met at depths of less than 200 feet. Below this first layer and separated from it by about 400 feet of shale is usually the second sand, but in some of the wells within this distance minor beds carrying water are encountered. Below the second main water sand and immediately overlying the tar zone (zone A) is a rather persistent stratum of sulphur water reported in most but not all of the wells. It is more commonly found in the deeper holes and may be represented in the wells toward the western part of the area and higher up on the dip by certain members of the tar-sand zone. If this is so it is interesting as showing that the hydrocarbons in the tar sand have been forced upward by the sulphur water which fills up this particular porous stratum, presumably under hydrostatic pressure.

Typical well log in Zier-Porter & Scribner-M., K. & T. area.

	Feet.
Surface formation of clay and sand with a little gravel	200
Water sand	20–40
Blue shale	350
Water sand or water gravel	40
Sulphur water sand, called the "main sulphur"	30–50
Blue shale or shells, a few feet.	
Alternating tar sands (zone A) and shale with 50 or more feet of shale and shell at the bottom	200
Productive 17° or 18° B. oil sand (zone B)	10–60
Series of alternating oil sands and blue and brown shales, including zone D..	300+

PRODUCT.

The production of the individual wells in this area varies from 40 or 50 barrels to a maximum of about 300 barrels per day. The gravity of the oil in those wells in the western part of the area well up on the dip is about 12° to 14° B., while in the deeper wells producing from the light-oil sand an average of about 17° or 18° B. oil is obtained. The deepest well in the area, the M., K. & T., is said to yield oil of about 16½° B. This oil is believed to come from zone D, in the Vaqueros (lower Miocene) formation.

ASSOCIATED—CALEDONIAN—UNION AREA.

LOCATION.

The area described under this heading embraces the region from the Union lease in sec. 13, T. 20 S., R. 14 E., southward to the southern part of section 36 in the same township and range. It includes well No. 3A and all other Associated wells north of this in section 36; also the properties of the Kern Trading and Oil (Southern Pacific Railroad), Caledonian, Ozark, Premier, Claremont, Wabash, Inca, St. Paul-Fresno, Coalinga Western, Coalinga Petroleum, Circle, Netherlands (formerly Valley Slope), San Juan (formerly Valley Slope), Coalinga Homestake (formerly Cawder), Traders (including what were formerly Angelus, Euclid, Marengo, and Norse), McQuigg & Wrenn (M. & W.) (formerly Blue Diamond), Arizona Petroleum (formery East Puente), St. Elmo (formerly New Home), Queen (formerly Coalinga Banner), S. A. Guiberson, Jr. (formerly Elgar Adams), American Petroleum (sections 18, 19, and 30), Nevada Petroleum (sections 18, 20, and 30), Valley, Coalinga, California (section 18), Maguire, Section One (formerly Coalinga Zenith), and Union oil companies.

STRUCTURE.

The wells in this area are located on the eastward-dipping monocline of the Westside field. Except for a local flexure, which is possibly the continuation of one of the lines of disturbance in the White

Creek syncline, the general position of the beds is regular, and they have an easterly dip of 11° to 22°. The beds apparently flatten out in passing east from the steeper hills in the western and southwestern parts of the area to the valley floor.

GEOLOGY OF THE WELLS.

The wells start down in the soft beds of the Etchegoin formation or of the immediately underlying Jacalitos and Santa Margarita (?) formations. Zone B, the one shown in contour on the map (Pl. XV), is the principal productive zone in this field, as in those farther north. In the northern part of the area the zone consists usually of a single medium to coarse grained sand varying in thickness from 20 to 30 feet. This thickness is fairly uniform throughout the northern part of the area, except in that portion well down on the dip, where the zone apparently is thicker and is penetrated for nearly 40 feet in some of the wells. It is also thicker locally toward the western edge of the area, 50 feet of productive sand being recorded in one of the shallower wells. It is believed, however, that in this well a part of the thickness is made up of intercalated shale. The top of zone B, especially in the southern part of the area, is usually indicated by the presence of oyster shells and *Tamiosoma* fragments in the wells.

Southward the sand apparently becomes less and less productive, the southernmost well so far drilled which is believed to obtain oil in commercial quantities from this zone being Associated No. 3A. Here the productive sand is practically of the same thickness as the average farther north, but in the wells still farther south the productive sand pinches out or is practically dry. Toward the east the productivity of zone B ceases along a practically north-south line passing near the middle of sec. 30, T. 20 S., R. 15 E. This is indicated by the nonproductiveness of zone B in the Nevada Petroleum wells, although the same zone is unusually productive in the American Petroleum wells, half a mile to the west. The gravity of the oil varies from 13° to 17° B., apparently being heavier toward the outcrop of the beds and lighter down the dip. A variation in gravity between 14° to 15° along the strike is also noticeable, the southernmost wells producing the lighter oil.

Although zone B is the first productive zone encountered in the wells, there is above it a tar sand called the Big Gumbo, which is penetrated by nearly all the wells from the Union south to the line of Associated wells along the north side of section 36. This gumbo sand, as the name implies, carries a heavy oil or tar, which has so far not been utilized in any of the wells. In the region of the Caledonian wells at the western edge of the developed territory, and farther up on the dip, there is still a higher oil sand, but this also is nonproductive.

Zone B consists of three well-defined oil sands throughout the region from the Union wells southward as far at least as the north edge of section 36. The uppermost of these sands varies from 10 to 50 feet in thickness, while the second is usually somewhat thinner. Hard shells are often associated with these lower sands, but in many of the wells blue shale is apparently the only parting. In some instances the sands below zone B are divided into three or four minor layers which show little regularity in thickness between the different wells. Toward the east from the township line of wells the upper sand of zone B first becomes unproductive, then the second sand, and finally the third near the middle of section 30 and the sections north and south of it.

The gravity of the oil in the lower beds of zone B is usually about the same as that in its upper beds, but in the Caledonian and Angelus regions an oil sand carrying 17° B. petroleum is found at the base of zone B. It is barely possible that this may be the equivalent of the light-oil sand in the region of the Coalinga Pacific and other wells of that same area, but it is the opinion of the writers that there is no direct connection between beds carrying the light oil in this southern part and the beds carrying oil of the same gravity in the region north of Los Gatos Creek.

In the region of the Wabash and Inca properties the oil sands are apparently the most regular of the Westside field, but on each side of this particularly regular area the variation in the sands is considerable from well to well, both along and across the strike of the beds.

A persistent stratum of sulphur-water sand is encountered in most of the wells between the Big Gumbo tar sand and zone B. This sulphur sand varies in thickness from about 10 to 20 feet, although in one of the Wabash wells it has apparently split up into two sands separated by shale, each sand member being somewhat less than 10 feet thick. In certain wells of this area the sulphur sand contains traces of oil, especially in those wells along the north side of section 36 and in some of the Union wells.

The formations above the zone of the Big Gumbo tar sand usually contain two or more water sands. In most of the wells the first sand is encountered at depths under 200 feet, but between this sand and the Big Gumbo the occurrence of water is irregular. In some of the wells water sand approximating 50 feet in thickness is encountered 200 feet below the first water sand, whereas in wells near by the second water sand may be only 10 feet thick and may be separated from the first sand by one or two other strata carrying water. The water from all of these sands is considerably mineralized and is not fit for domestic uses.

Typical well log, Associated-Caledonian-Union area.

	Feet.
Shale	150
Water sand	20–30
Shale, with some dry sand or gravel	200
Water sand	20–50
Blue shale, with some dry sands and occasionally some water sand	600
Tar zone (zone A)	8–50
Blue shale	20–100
Sulphur-water sand	20
Blue shale, with occasionally fine sand layers	100–200
Zone B, consisting of various oil sands of more or less importance, the whole being thinnest near the outcrop and thickening gradually down the dip	100–225

The water is generally shut off in the upper part of the blue-shale zone overlying zone B. Such a proceeding is doubtless flooding the Big Gumbo sand, but as this tar sand is not believed to be productive in any part of the field the flooding is doing no harm. In the Nevada Petroleum and Valley wells the water is shut off below the water sand which underlies zone B, but this proceeding, although flooding zone B, will simply tend to drive the oil upward and westward into the wells where zone B is productive.

One of the Caledonian wells was drilled to a depth of over 2,300 feet, but from the depth of somewhat over 700 feet it passed through the usually unproductive brown and blue shales of the Tejon (Eocene), yielding warm salt water of 110° F. near the bottom. Sulphur water was also encountered at about 1,600 feet in this well, and a little greenish oil of over 17° gravity was encountered near the 1,000-foot mark. The base of the productive measures in the western part of this area is believed to be marked by a persistent stratum of salt or brackish water, which is encountered in those wells which have been drilled into the underlying Tejon.

PRODUCT.

The product in the wells so far drilled in this area comes from zone B, the Jacalitos (upper Miocene) zone. The daily production of the individual wells varies from about 1,500 barrels in the deeper wells to 50 or 60 barrels in the shallower. Many of the wells flow at first and some of the deeper ones continue to flow for two or three years, but most of the wells are pumped after the initial head of gas has blown off. Much sand accompanies the oil, the proportion being as high as 50 per cent at first in some of the wells. Large amounts of gas are produced by most of the wells. The gravity of the oil varies from 12° B. in the shallow wells, those upon the dip, to 17° for the deeper holes. Three sands are recognized in the productive zone, the upper one yielding the lightest oil.

AREA BETWEEN WALTHAM CREEK AND SAN JOAQUIN VALLEY COAL MINE.

LOCATION.

The area treated in the following paragraphs comprises the territory lying between the Cretaceous-Vaqueros (lower Miocene) contact, which extends northwestward from Alcalde, and the valley floor west of Coalinga, and between Waltham Creek and the region of the San Joaquin Valley coal mine in the NW. ¼ sec. 26, T. 20 S., R. 14 E. A portion of this region, namely, that in which the wells of the Sunnyside and Westlake-Rommel oil companies are situated, will be considered separately, following the discussion of the major portion of the area. The oil companies in the region here discussed include the Mount Hamilton, Commercial Petroleum, Summit, Elaine, Lucile, Shreeve, Associated, Kern Trading and Oil (formerly Southern Pacific Railroad), Yellowstone (formerly Coalinga Southern), Sauer Dough, Jefferson (formerly Section Six), California Gas and Oil (formerly T. C.), De Lux, Amy, Silver Tip, Red Top, Aladdin, Muriel (formerly St. Francis), Waratah, Marion (formerly St. Clair), Los Angeles-Coalinga Oil Syndicate, Section One (formerly Coalinga Zenith), Coalinga Great Western (formerly West Coalinga), Smith & Porter (formerly Summit), and some others not yet prosecuting development work.

GEOLOGY.

The formations involved in the geology of this area comprise the Cretaceous (Knoxville-Chico) sandstone and shale, the Eocene (Tejon) sandstone and shale, a series of sandstones overlain by soft shale, which are believed to be largely of Vaqueros (lower Miocene) age, the sandstone, conglomerate, and shale of the Jacalitos (early upper Miocene) formation, and sand and clay shale of the Etchegoin (late upper Miocene).

The Knoxville-Chico (Cretaceous) consists of dark thin-bedded shale with some sandstone, the latter in places carrying the characteristic brown concretions. It outcrops west of the area under discussion and extends in a northwesterly direction into the hills south of Los Gatos Creek. In the main the Cretaceous beds are steeply tilted, forming a monocline with an approximate dip of 60° SE. They carry no oil, but are believed to yield the water in the Henshaw and West Coalinga wells.

The Tejon (Eocene) consists largely of medium-grained sandstone with some intercalated shales at the base and a considerable thickness of shale at the top. The Tejon occupies a small area in the SW. ¼ sec. 26, T. 20 S., R. 14 E., immediately south of the San Joaquin Valley coal mine. Except this small outcrop the Tejon in this area is entirely covered up by the later beds, which overlap it from the east and south. The basal Tejon overlies the Cretaceous, appar-

ently conformably, and dips northeastward at an angle of about 30° and is itself in turn overlain unconformably by the Miocene beds.

Unconformably overlying the Knoxville-Chico (Cretaceous) and the Tejon (Eocene) just described, is a series of beds consisting of about 250 feet of sandstones and over 100 feet of soft dark-blue shale. These beds are known to be Vaqueros at the base, but the age of the uppermost member, the shale, is unknown. However, it may possibly be the equivalent of the Big Blue in the north end of the Coalinga field, although in the area under discussion it has been mapped with the Vaqueros, and in the Eastside field it is included in the Santa Margarita (?) formation. The basal sandstone of the Vaqueros formation may be traced from a short distance south of the San Joaquin Valley coal mine southward across the northwest corner of sec. 35, T. 20 S., R. 14 E., along the western edge of the same section, into the middle of the NW. ¼ sec. 2, T. 21 S., R. 14 E., thence southeasterly to the bottom of the canyon near the middle of the south line of the SE. ¼ sec. 2. Thence it passes westward below and north of the summit of the big ridge which extends several miles northwestward from Alcalde. Near the San Joaquin Valley coal mine the Vaqueros overlies the Tejon (Eocene), but near the northwest corner of section 35 it crosses the contact between the Knoxville-Chico (Cretaceous) and the Tejon, and thence southwestward it overlies the Knoxville-Chico. The contact between the Knoxville-Chico and the Tejon is believed to extend southeastward underneath the Vaqueros diagonally through sec. 35, T. 20 S., R. 14 E., and diagonally through sec. 1, T. 21 S., R. 14 E. Its course from the latter region is not definitely known, but can be surmised as stated on pages 238–239. The tracing of this contact beneath the Vaqueros is important, because the oil is derived from the Eocene shale, and it is believed that wherever the Vaqueros or other formations overlie the Tejon they will be found more or less petroliferous, while in the areas where the same formations overlie the Knoxville-Chico they will be found barren or to contain only such petroleum as has migrated along the strata from areas underlain by the Tejon. It is worthy of note in this connection that along practically the whole extent of the outcrop of the base of the Vaqueros from the San Joaquin Valley coal mine southward to the southern part of sec. 2, T. 21 S., R. 14 E., the basal beds are more or less petroliferous. The indications are so strong in certain places, notably in the SE. ¼ sec. 2, that tunnels have been run into the base of the Vaqueros sands with the expectation of obtaining petroleum in commercial quantities.

Westward from the southeastern part of section 2 the basal sands of the Vaqueros become less and less petroliferous, until on the flanks of the ridge spoken of as extending northwestward from Alcalde the beds show no indications of petroleum.

The description of the geologic section exposed on the surface along a line extending from the middle of the south line of sec. 2, T. 21 S., R. 14 E., in Anticline Canyon, to the top of Flag Hill, in the SE. ¼ sec. 1, T. 21 S., R. 14 E. (shown as the triangulation station on the topographic map), and thence in a direct line to the Lucile well, epitomizes the formations of the area under discussion. This section is based upon a detailed surface traverse and in a general way upon the well logs of sections 6 and 36 to the northeast.

Explanation of hypothetical section (fig. 8) along line F-F' on contour map (Pl. XV), from Anticline Canyon to California Oil and Gas Company's well No. 1, beginning with lower strata.

[Dip approximately 20° NE.]

Vaqueros (lower Miocene), beds *a*, *b*, *c*, and *d*.

a. Much discolored and rusty-yellowish sand and soft sandstone, highly charged with petroleum in the immediate vicinity of Anticline Canyon, and about 150 feet thick. Not yet pierced by any of the wells in the section 6 area, but believed to be a rich oil-bearing sand throughout its thickness. Represents the basal part of zone D of the developed territory.

b. Largely gypsiferous sand, with a hard fossiliferous layer at the base. The fossils, which are abundant in Anticline Canyon a short distance below the south line of section 2, are believed to be from the same bed as the fossil "clam" shells thrown out in the sand from the bottom of Lucile well No. 1. About 150 feet thick; probably represents parts of oil zones C and D in the Eastside field.

c. Soft sand with pebbly layers and occasional hard, coarse, rusty sandstone strata which would be called "sandstone shell" if encountered in the wells. About 200 feet thick, and also a part of zones C and D. Beds *b* and *c* apparently thin out slightly toward the valley, as the thickness disclosed by the well logs is somewhat less than that obtained by calculation from the surface outcrops.

d. Largely clay, about 250 feet thick; may be the equivalent of the Big Blue in the Eastside field.

Jacalitos (early upper Miocene), beds *e*, *f*, *g*, *h*, *i*, *j*, and *k*.

e. Largely pebbly gravel overlain by thin-bedded sand and soft sandstone. Bed of fossils, largely *Zirphæa*, at top; believed to be the ones reported in both the Shreeve and Lucile logs. These are an important tie line, not only in this particular area, but also throughout the Coalinga district. Bed believed to be the same as that which rests upon or near the shales of the Tejon west of that part of the Westside field lying north of the San Joaquin Valley coal mine, and believed to be of upper Miocene age. It is zone B in the wells of the south and central parts of the Westside field, and is between 100 and 200 feet in thickness.

f. Above the fossil bed are some coarse gray sand layers. Well in northeast corner of the SW. ¼ sec. 12, T. 21 S., R. 14 E., begins in this zone of sand.

g. Consists of clay shale and apparently thickens somewhat toward the valley, especially between the Shreeve and Lucile wells.

h. A persistent layer of soft, pebbly sandstone, recognized in both the Shreeve and Lucile well logs.

i. Ten-foot layer of clay.

j. Another pebbly sandstone layer, apparently not so persistent as bed *h*.

k. An important and widespread blue clay.

Etchegoin (uppermost Miocene), beds *l*, *m*, *n*, *o*, *p*, and *q*.

l. This sand zone consists of brown sand at the base, 10 feet of hard sandstone above it, then a layer of sand, another layer of sandstone, and finally a soft sandstone at the top.

m. Soft blue shale, 15 to 200 feet thick.

n. Coarse brown to greenish pebbly sand at the base, overlain by coarse brown sand containing numerous large fossil sand dollars, *Echinarachnius gibbsii* Rémond. About 125 feet thick.

o. Sand and soft sandstone, pebbly at the bottom, with numerous fossils. Known as a fossil bed in the wells in some parts of the field; contains such species as *Pecten oweni* Arnold, *Glycymeris*, etc. It is the *Glycymeris* zone, not far above the base of the Etchegoin formation.

p. Bluish clay about 100 feet thick.

q. From bed *q* down to the detritus-covered valley floor in the vicinity of the Lucile well No. 1 the beds exposed are largely coarse sands with occasional pebbly layers. Toward the edge of the hills some of the beds contain cobbles of considerable size and fossils indicating the same horizon as the *Pecten coalingaensis* zone, near the top of the Etchegoin in the Kreyenhagen Hills. Usually spoken of by the drillers as "surface formation," as they appear to be largely incoherent and of heterogeneous character. Total thickness of the Etchegoin exposed is about 750 feet. Uppermost beds in the wells possibly represent a part of the Tulare formation.

STRUCTURE.

The main structural feature governing the area under discussion is of course the great southeastward-dipping monocline which extends from the top of Curry Mountain and Juniper Ridge to the middle of Pleasant Valley. There are, however, one or two local lines of disturbance within the area which are worthy of mention. The most important begins in the Knoxville-Chico (Cretaceous) somewhere northwest of sec. 2, T. 21 S., R. 14 E., and passes southeastward, apparently almost coincident with the bed of Anticline Canyon. From the south line of section 2 to the middle of the E. ½ SW. ¼ sec. 12, this line of disturbance has the character of a southeastward-plunging anticline. The dips to the east are apparently about 20°, while those toward the south vary from 8° or 10° in the region immediately south of section 2 to 30° or 40° in the southern part of the SW. ¼ sec. 12. At a point a short distance west of the east line of the SW. ¼ sec. 12 the line of disturbance bends abruptly and passes almost due east for nearly three-fourths of a mile. Along this east-west portion the disturbance takes the form of a fault at the surface, although the beds in a general way dip away on both sides of the fault line. The line of fracture may be traced from the dome of the anticline in the east wall of Anticline Canyon, in the eastern part of the SW. ¼ sec. 12, to a point less than one-fourth mile northeast of the Commercial Petroleum Company's well No. 1, in the SE. ¼ sec. 12. The beds on the south side of the fault are inclined in a southerly direction, with dips varying from 60° or 70°

near the fracture to 35° or 40° some distance south of it. North of the fracture the beds dip about 20° NE. and abut sharply against the steep southward-dipping beds. From the east line of the SE. ¼ sec. 12 the line of fracture apparently bends abruptly toward the southeast and either dies out beneath the superficial deposits of Alcalde Canyon or is connected in some way with the Jacalitos anticline.

A minor disturbance, probably intimately connected with the one just described, is developed in an east-west ridge in the NE. ¼ sec. 7, T. 21 S., R. 15 E. An examination of the surface geology of this region, beginning at the railroad cut in the NW. ¼ sec. 8, T. 21 S., R. 15 E., discloses, first, coarse sandstone beds dipping 10° to 50° N. 35° E.; thence westward along the crest of the ridge dips of 16° N. 25° W. are first encountered, then dips of 20° a little farther west, and finally, where the strike of the beds swings around northwest, the dip is as high as 40°. Northwestward from this maximum dip the beds drop to 30° NE. and finally to the prevailing dip of 18° to 20° along the western side of section 6.

A third line of disturbance is visible in the small bluff on the northwest side of Alcalde Canyon, immediately north of Alcalde station. This is a sharp anticlinal fold in gray and brown shale with a dip of 20° S. 53° W. on the one side and 70° N. 55° E. on the other. Mount Hamilton well No. 1 is drilled practically on the axis of this anticline, less than one-fourth mile from the bluff mentioned. An examination of the territory northwest of the Mount Hamilton well, embracing the territory along the contact between the Knoxville-Chico and the Tejon, discloses dips that apparently indicate a northwestward continuation of the anticline as far as the SE. ¼ sec. 10, T. 21 S., R. 14 E. The beds in this region lie so nearly horizontal and have been so affected by landslides that it is impossible to determine definitely the course of the line of disturbance. This structural feature, however, has no apparent influence whatever upon the oil-bearing beds, but is described simply to indicate where the forces produced folding in the beds.

Still a fourth line of disturbance enters the area under discussion in the southwestern part of sec. 7, T. 21 S., R. 15 E. This is the Jacalitos syncline, which is prominently developed farther south and will be described in the discussion of the area south of Waltham Creek. In the southwest corner of section 7 this syncline produces dips of 40° S. 20° W.; a short distance south the same bed dips 30° nearly due east, a little farther south 25° in the same direction, and still farther south 20°. This syncline is apparently associated with the Anticline Canyon flexure, but the relations between the two are obscured by the detrital material of Waltham Creek at the critical point along the south line of section 7.

In connection with the folding and faulting which has taken place in section 12, it might be well to discuss the geology in the vicinity of the Commercial Petroleum well No. 1, in the southeast corner of the SE. ¼ sec. 12, T. 21 S., R. 14 E. A section along the surface of the ridge northward from this well shows the following strata, all dipping about 60° approximately due south.

Section in Miocene north from Commercial Petroleum Company's well No. 1, sec. 12, T. 21 S., R. 14 E.

	Feet.
Soft sand	30
Pebbly sand	40
Soft sand	180
Coarse sand with hard dark layers ("shells")	240
Fine pebbly sand (the dip here is 60° due south)	255
Alternating coarse sandstone and pebbly sandstone beds with a particularly hard brown sand layer at the base	320
Soft blue shale and sandy shale	620
Coarse pebbly sand, the last half hard and containing silicified wood fragments (dip is 50° S.)	710
Gray sand with one or two hard streaks	760
Soft blue gypsiferous shale	790
Medium to coarse gray sandstone	820

At 820 feet is the fault line extending S. 80° E. The downthrow is on the north and is probably at least 200 feet. The beds along the trace of the fault are of a purplish and pink tint, this discoloration probably being due to petroleum which has seeped up along the fault. A comparison of the surface section and the log of the Commercial Petroleum well indicates the reason for the discrepancy between this well log and those of the wells in the section 6 area. In the Commercial Petroleum well the beds penetrated dip 60° or so, while the beds in the section 6 area dip less than 20°. The water in the Commercial Petroleum well is probably local, and is to be associated with the fault line which the well apparently cuts near the junction of the well with the oil sand. It is the belief of the writers that it would be impossible to put down wells in this faulted area and obtain the same or even approximate results in any two. The region about the corners of secs. 12 and 13, T. 21 S., R. 14 E., and secs. 7 and 18, T. 21 S., R. 15 E., is the center of a number of complex disturbances, which are believed so to complicate the underground geology locally as to make the exploitation of the oil sands difficult if not impossible.

GEOLOGY OF THE WELLS.

The wells in this area [a] lie for the most part on the south-southeastward continuation of the great eastward-dipping monocline

[a] Wells drilled in this district since the publication of the writers' preliminary report (Bull. U. S. Geol. Survey No. 357, Nov. 23, 1908) have shown that certain of the conclusions drawn regarding sec. 6, T. 21 S., R. 15 E., were erroneous. These, together with Plate III of that report, have therefore been revised to agree with the latest data obtainable October 15, 1909.

which controls the oil-bearing formation of the Westside field. Somewhere south of sec. 6, T. 21 S., R. 15 E., probably in section 7 or 18, the strike changes to an easterly direction as the result of movements along the Jacalitos anticline and associated structural lines. It will be noticed by an examination of the contour map (Pl. XV) that the formations have a practically uniform dip of about 18° or 20° down to the edge of the more pronounced hills. At the edge of the hills the dip flattens out considerably. It should be observed in this connection that the topography in a general way reflects this change in dip. This is an important item to remember, as in other parts of the field where there are no wells and in which surface outcrops are lacking it may be possible to judge in a general way of the position of the underground formations by a critical examination of the topography of the region under observation. As a result of the bowing of the strata the dips are apparently steepest in section 36, but flatten out and become more regular north of this area. In the southern part of section 6 and also the northern part of section 7 the dips are very steep at the surface outcrop. The locus of the steep dip apparently extends from the surface underground in a northerly direction and has its maximum effect on the oil sands in the NW. ¼ sec. 6 and in the SE. ¼ sec. 36. Details of the change in dips and strike are indicated by contours on the map (Pl. XV), and will not be discussed further here.

All of the wells within this area start down in the soft surface sands and clays, which, below the uppermost superficial stratum, are believed to belong to the Etchegoin or possibly to the Tulare formation. Before reaching the uppermost oil zone (zone B) the wells pass through four or five well-defined zones of sandstone with as many interbedded layers of soft blue shale. Many of the sands carry pebbles up to the size of a marble, and some of the blue shales are also pebbly. Water sands are encountered at various depths, some of them producing large quantities of more or less mineralized water. The Lucile well No. 1 and the West Coalinga well No. 1 produce a great deal of water, but from entirely different formations, the first from the Jacalitos (upper Miocene), the latter probably from the Knoxville-Chico (Cretaceous). Water is usually encountered between zones B and D, one sand in the base of or just below zone B carrying sulphur in some of the wells, and another persistent layer occurring just above zone D. Water is also encountered between the uppermost or fine-grained light-oil sand and the next sand (heavy-oil sand) below in zone D. This last-mentioned water stratum is believed to yield the water produced with the oil in the Lucile No. 1, Aladdin, and near-by wells which have penetrated the heavy-oil beds. Where the heavy-oil strata of zone D are lacking, as in certain of the wells in the western part of section 6, water marks the base of the productive zone, which here consists only of the uppermost strata of

zone D. Some very hard sandstone shell layers are encountered in the wells, and in one or two places these appear to be rather persistent laterally. The hard layer reported as the "big shell" in some of the wells is apparently not the same stratum that is designated by that name in certain others.

The first oil zone (zone B) varies in thickness from about 60 to 150 feet. In some of the wells it is reported as nearly solid sand, while in others it is a zone of alternating sandstone and shale. Oil or gas or both are reported from it in a few of the deeper wells, but in most the zone is apparently dry. It is believed that indications of petroleum must have been found in this well and overlooked by the driller, or else they were not considered of enough importance to record in the log. So far as known no well in this area produces from this zone. The individual sands of zone B vary from fine-grained thin-bedded layers intercalated with sandy shale to coarse conglomeratic sand carrying small cobbles. As previously mentioned, this zone may be studied in the east wall of the canyon running up to the Henshaw water well (SW. ¼ sec. 35, T. 20 S., R. 14 E.), about half a mile southeast of this well.

Oil zone B is underlain by a persistent stratum of mineralized water, either salt or sulphur or both, in nearly all the wells. In some this flow of water was encountered at the base of a hard sandstone shell underlying the oil strata, but in others it is reported in the lowest oil sand of the zone. Oil zone B is separated from the lower or zone D by between 150 and 200 feet of shale and shell. Some water sands and tar sands are reported in the space between zones B and D in some of the wells, but these do not appear to be very persistent. Most of the wells have penetrated zone D, but touch only its uppermost sands. The reason for this is generally that the gas pressure is great enough either to make the well flow or to fill it up with sand. The uppermost beds of zone D are fine grained and carry oil of fairly light gravity. Oil of 32° B. has been reported in one of the wells, and the gravity of all the upper beds seems to range from this down to 22° B.

Below the zone of light-oil sands is a coarser sand carrying fossil shells and believed to be the same as the bed at the base of bed *b* in the section given on page 191. The oil from this lower zone is much heavier than that from the upper and averages somewhere near 16° or 17° B. in gravity; the lower sand also is very much more productive than the finer sands and is therefore tapped wherever possible. It is the belief of the writers that this lower oil sand will furnish long-lived wells, for the holes which simply tap its uppermost layers are very productive, and the 150 or 200 feet of sands which are believed to underlie the upper beds in the deeper wells are doubtless heavily impregnated with oil.

The following is a log characteristic of the wells in this area:

Log of Aladdin Oil Company's well No. 1, sec. 6, T. 21 S., R. 15 E.

	Feet.
Brown sandy formation	320
Dark water sand	395
Brown shale	500
Sand and gravel	515
Blue shale	560
Brown shale	605
Blue shale	685
Dark sand	705
Blue shale	728
Water sand	750
Blue shale	810
Shale and shells	900
Blue shale	1,000
Shale and shells	1,055
Sand	1,070
Shale and shells	1,150
Dark sand	1,190
Shale and shells	1,240
Sand	1,258
Shells and shale	1,330
Hard sandstone (underreamed)	1,350
Sticky blue	1,370
Sandy shale	1,410
Hard blue clay	1,425
Blue shell and shales	1,460
Sandy shale	1,475
Hard sandstone	1,490
Sticky blue	1,515
Sandy shale	1,520
Shell	1,522
Sticky blue	1,590
Sandy shale	1,660
Gray shale	1,700
Blue shale	1,750
Sand and gravel	1,780
Hard conglomerate	1,815
Sand	1,840
Blue shale	1,875
Blue and sandy shale	2,012
Sand and broken shale	2,060
Sticky blue shale	2,115
Pebbles and sand	2,118
Shale (underreamed)	2,168
Shell (underreamed)	2,170
Shale (underreamed)	2,205
Sandy shale	2,218
Sand and shells (underreamed)	2,290
Sticky blue clay	2,360

	Feet.
Blue shale and shells	2,440
Shale	2,485
Dark sand	2,505
Oil sand, white	2,530
Hard oil sand	2,533
Coarse oil sand	2,543
Hard shell	2,558
Oil sand and oyster shell	2,585

PRODUCT.

The daily yield of the individual productive wells in the area under discussion varies from about 100 barrels for those up on the dip to about 800 barrels in the deeper holes. An initial production of over 1,500 barrels per day is said to have come from one of the wells. Oil of 26° B. gravity is yielded by sands at the top of the lower zone (zone D), and as high as 175 barrels of oil per day is said to have been produced by one well from these sands alone. Below the light-oil sands are coarser and more productive layers which yield the bulk of the oil for this territory. The gravity of the petroleum from this last horizon is between 16° and 17° B. The oil in light-oil sands is brown; that in the zone of heavier oil black.

The most phenomenal well in this area is the Silver Tip, which gushed gas, sand, and oil when zone D was first penetrated, then sanded up, and finally, when it was cleaned out, gushed a second time at the rate of 20,000 barrels a day for a few hours. For the first few days of its productiveness it flowed and sanded intermittently; after two months it is now (November 1, 1909) yielding 2,500 barrels a day.

AREA EMBRACING SEC. 2, T. 21 S., R. 14 E.

LOCATION.

Under this heading will be discussed the underground geology in the E. ½ sec. 2, T. 21 S., R. 14 E., and the southern part of sec. 32, T. 20 S., R. 14 E., which has been tested by the wells of the Sunnyside Oil Company (Henshaw water well) and Westlake-Rommel Oil Company.

GEOLOGY OF THE WELLS.

The wells in this area penetrate the northeastward-dipping beds of the Vaqueros (lower Miocene), which overlie the steeply tilted Knoxville-Chico (Cretaceous) strata exposed at the surface toward the west. The oil in this area is believed to have percolated along the basal or zone D sands from the territory toward the east, where these sands overlie the shales of the Tejon (Eocene) formation. Only four wells have so far been put down in this area. Three of these were

sunk several years ago by the Westlake-Rommel Company and the other is the Henshaw water well, which was put down by Captain McClurg for the Sunnyside Oil Company in 1897. The logs of these wells indicate that the petroliferous zone is from 100 to 120 feet thick and consists of medium-grained sands interbedded, especially toward the middle of the zone, with fine clays and harder sand layers. The sand carries a little heavy oil and in the Westlake-Rommel wells is said to have yielded no gas. This lack of gas would be expected in an area so close to the outcrop of the oil sands, where the gas would have an opportunity to escape from them. Water is found associated with the oil in the uppermost layer of this zone in one of the wells and is found abundantly in the sands just beneath the oil zone. In addition to the four wells mentioned, tunnels have been run in on the outcrop of the oil sands in the E. ½ sec. 2, but not enough oil was obtained from them to pay for their operation.

It is believed that the Henshaw well obtains its water supply from a sand in the Knoxville-Chico (Cretaceous), as the depth at which the sand is penetrated is considerably lower than the base of the Vaqueros formation. As the Knoxville-Chico beds in this region are highly tilted, there is probably but a narrow band along which wells put down with the expectation of tapping the Henshaw water sand will be able to reach it. The strike of the Knoxville-Chico is here about east-northeast, so that it is believed that this band strikes in a direction north-northwest or south-southeast of the Henshaw well.

PRODUCT.

The discussion of the product accompanying the preceding area (p. 226) applies to the whole region between Waltham Creek and the San Joaquin Valley coal mine.

KREYENHAGEN FIELD.

LOCATION.

The region south of Coalinga as far as Dudley, Kings County, including the Kettleman and Kreyenhagen hills and Reef Ridge, has been known for many years as the Kreyenhagen oil district. For the sake of brevity of discussion in the present report this territory has been included as a part of the Coalinga district and has been divided into two fields, the Kreyenhagen field and the Kettleman Hills field.

The area discussed as the Kreyenhagen field lies on the southeastern flanks of Reef Ridge and extends from the general region of Jacalitos Creek to Dagany Gap, 3½ miles southeast of Dudley. The area in which oil development has been carried on is a narrow band between Canoas Creek and the region of Big Tar Canyon.

CONTOUR MAP.

The contour map of the Kreyenhagen field (Pl. XXII) is intended primarily to give a generalized representation of the monocline on the northeastern flanks of Reef Ridge and the rate at which the formations pitch below the surface. The underground contour lines indicate the approximate depth above (marked +) and below (marked −) sea level of the upper portion of the Vaqueros sandstone or the lower portion of the hard white shales mapped as Santa Margarita(?) formation; in other words, the distance below sea level of the horizon that is supposed to be the highest one at which oil may be found.

The structural lines on this map were drawn solely on the basis of the apparent dip of the beds on the surface and without the aid of any underground data such as are afforded by the oil wells in the Coalinga field. The contours are entirely hypothetical.

GENERAL GEOLOGY AND OCCURRENCE OF OIL.

Reef Ridge and the region immediately adjacent to it, both southwest and northeast, are a part of the great monocline of rocks which forms the east flank of the main Diablo Range. The formations involved in the geology are the conglomerates, sandstones, and shales of the Knoxville-Chico (Cretaceous); the sandstones and shales of the Tejon (Eocene); the sandstone and shale of the Vaqueros (lower Miocene); the shale of the Santa Margarita (?) (upper middle Miocene); and the sandstone, shale, and gravel of the Jacalitos formation (upper Miocene). The oil, as in the Coalinga field proper, is believed to have originated in the shales of the Tejon formation, but has migrated to the sandstones of the Tejon that underlie the shales of that formation, to sands interbedded with those shales, and to the overlying Vaqueros sandstone. Numerous tar springs that rise from the Tejon and Vaqueros within the area under discussion show that those formations contain oil. Among the principal springs of this kind may be mentioned those in Canoas Creek, which come from the upper part of the Vaqueros; those on or near the Clark ranch farther south, in the vicinity of Garza Creek, also in the Vaqueros; the famous tar spring in Big Tar Canyon, which comes from the upper part of the Tejon; and the springs in Little Tar Canyon and north of it, which come from the upper part of the shales of the Tejon. Numerous other seepages and springs are found along the outcrop of the Tejon and Vaqueros, but within the area mapped none, to the knowledge of the writers, are found farther north than Canoas Creek or farther south than the head of Little Tar Canyon.

Indications of petroleum are found in the basal shale layers in the Tent Hills anticline 2 miles southeast of Dudley, but no true seep-

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ages are known between the one in Little Tar Canyon and Sulphur Spring, in the Devils Den district. The Castle Mountain fault, which cuts off the Tejon and Vaqueros formations near the head of Little Tar Canyon, is believed also to eliminate these same formations below the Santa Margarita (?) formation southward for a considerable distance below the head of Little Tar Canyon. Owing to the steep dip in the formations along Reef Ridge the petroliferous zone is necessarily very narrow. The extent of the zone in which it seems possible that productive wells may be put down is shown on the map (Pl. I). Water accompanies the oil in all the seepages along this belt and has caused the failure of many test holes, which will be described later.

GROUPS OF WELLS DISCUSSED.

The wells in the Kreyenhagen field may be divided into two groups, those which have been sunk in the Tejon (Eocene) formation and those which start in strata above or younger than the Tejon. The wells in the first group, enumerated from north to south, include those of the Kreyenhagen Oil Company, Kings County Oil Company, Consolidated Oil and Development Company, Baby King Oil Company, and Avenal Land and Oil Company. The wells in the second group, enumerated in the same direction, include those of the Black Mountain Oil Company, Kings County Oil Company, St. Lawrence Oil Company, and El Cerrito Oil Company (formerly known as the Anderson well).

GEOLOGY OF WELLS IN THE TEJON FORMATION.

The two wells of the Kreyenhagen Oil Company are located on Canoas Creek, in the SE. ¼ sec. 32, T. 22 S., R. 16 E. Both wells start in the shale in the upper part of the Tejon, the southernmost, well No. 1, beginning lowest in the formation. This well (No. 1) penetrated 650 feet of dark-colored shale, finding water at 125 and at 400 feet, and ended in 10 feet of oil sand.

An examination of the geology immediately south of this well indicates that the oil sand is very much thicker than is indicated by this log; just how far below the shale the sand is impregnated it was not possible to determine accurately, but on the surface the sand showed signs of petroleum for a thickness of over 100 feet. Well No. 1 is said to have yielded about 15 barrels per day at the start, soon falling to 5 or 6 barrels. The product is said to be a light-green oil, with gravity between 37° and 38° B. No water accompanied it. Well No. 2 of the same company is located north of well No. 1 and higher in the formation. It is said to have struck traces of oil at 1,000 and 1,100 feet and to have attained a depth of about 1,200 feet, at which point water was encountered. This well (No. 2) never produced commercial quantities of oil.

The Kings County Oil Company sunk a well in the SW. ¼ SW. ¼ sec. 3, T. 23 S., R. 16 E. This location implies that the well started at about the middle of the band of the Tejon formation that covers that vicinity. The well is said to have passed through black shale, blue sandstone, and brown sandstone containing oil, but was abandoned on account of water.

The Consolidated Oil and Development Company sunk two wells in the Tejon (Eocene) formation in the NE. ¼ sec. 10, T. 23 S., R. 16 E. One of the wells reached a depth of 1,100 feet and is said to have obtained a good showing of 20° B. amber-colored oil at a depth of 1,050 feet. The difference in gravity between this oil and that obtained from the same formation in the Kreyenhagen well is not easily explained.

The well of the Baby King Oil Company is located immediately behind Reef Ridge, in the NE. ¼ sec. 11, T. 23 S., R. 16 E., in the canyon of the first stream west of Big Tar Canyon. It starts down in strata lying near the contact between the Tejon (Eocene) and Vaqueros (lower Miocene) formations. It is said to have struck oil of 30° B. gravity at 400 feet and oil of 18° B. gravity at 1,110 feet; a short distance below this last point flowing water was encountered. At the time of the writers' visit in September, 1907, the well was flowing about one-half miner's inch of water, accompanied by occasional blebs of black heavy oil and some gas.

The Avenal Land and Oil Company has two wells in the E. ½ E. ½ sec. 18, T. 23 S., R. 17 E., not far from the famous tar spring in Big Tar Canyon. Well No. 1, the western of the two, starts down in the soft oil-stained sand beds of the Tejon (Eocene) or possibly Vaqueros (lower Miocene) immediately underlying the lowest hard sandstone bed of the Vaqueros. The log of this well is as follows:

Log of well No. 1, Avenal Land and Oil Company, E. ½ E. ½ sec. 18, T. 23 S., R. 17 E.

	Feet.
Adobe	20
Oil sand with water	70
Blue water sand	140
Clay	235
Shale	521
Oil sand	555
Shale	590
Sand showing traces of oil	635
Shale	802
Blue clay	900
Sand with traces of oil (not finished)	984

This well is said to have yielded less than 2 barrels per day of dark-colored 28° B. oil. Well No. 2 starts well down in the Tejon and is said to have gone through soft sand to 1,045 feet, where a productive sand was encountered. It yielded some oil when bailed.

GEOLOGY OF WELLS IN FORMATIONS ABOVE THE TEJON.

The Black Mountain Oil Company sank two wells in the SW. ¼ NW. ¼ sec. 33, T. 22 S., R. 16 E. These wells both start down in the dark shale of the Santa Margarita (?) formation and obtain their oil from the top of the Vaqueros sandstone. The log of well No. 1 of this company is as follows:

Log of well No. 1, Black Mountain Oil Company, SW. ¼ NW. ¼ sec. 33, T. 22 S., R. 16 E.

	Feet.
Dark-colored shale	80
White sand	85
Dark-colored shale	400
Light-colored shale	550
Shale and sand with oil	570
Light-colored shale	640
Oil sand	660
Shale	700
Oil sand	720

This well is said to have produced 5 or 6 barrels of black, 18° B. oil. The second well is located 600 feet north of No. 1, but no data concerning it are available.

The Kings County Oil Company sank a well in the SW. ¼ NE. ¼ sec. 3, T. 23 S., R. 16 E., which is believed to start toward the bottom of the Santa Margarita (?) formation (upper middle Miocene) and to obtain its oil from the Vaqueros (lower Miocene). The log of this well is as follows:

Log of well of Kings County Oil Company in SW. ¼ NE. ¼ sec. 3, T. 23 S., R. 16 E.

	Feet.
Clay and soil	12
White shale	29
Black shale	65
Black sand	67
Black shale	90
Hard gravel	120
Black shale (heavy oil at 240 feet)	275
Gravel	285
Black shale	410
Blue sand rock	450
Water sand	490
Blue sand rock	540
Sand	556
Clayey sandstone	600
Black shale	660
Clayey sandstones	696
Hard shale	720
Hard rock, sandstone predominating	950

Another well was started by the same company but never finished.

The St. Lawrence Oil Company is said to have sunk a well in the SE. ¼ NE. ¼ sec. 12, T. 23 S., R. 16 E., which encountered oil near

the bottom. This well doubtless began in the Santa Margarita (?) and penetrated the oil sands at the top of the Vaqueros (lower Miocene).

A. M. Anderson and associates (El Cerrito Oil Company) were drilling in the summer of 1908 on a well in the NW. ¼ sec. 14, T. 23 S., R. 17 E. The well starts down near the contact between the Etchegoin (upper Miocene) and Tulare (Pliocene-Pleistocene) formations, and is said to have been located on the evidence of a supposed oil-sand outcrop a few hundred feet south of the well site.

KETTLEMAN HILLS FIELD.

LOCATION.

Development work within the Kettleman Hills has been confined to their northern portion, all the wells started having been put down on the flanks of the hills at some distance from the axis of the Coalinga anticline, which runs parallel with and east of the topographic axis of the hills.

GEOLOGY AND INDICATIONS OF OIL.

The formations which rise to the surface in the anticline are the Etchegoin and Tulare, described fully under "Geology." The structure of the hills is that of a simple arched anticline, with low dips near the axis and steeper ones toward the flanks. The maximum dip on the northeast flank is about 31°; that on the southwest 45°. The late W. P. Kerr informed the senior author that he was told by one of the government land surveyors who visited the Kettleman Hills over twenty years ago that at that time the surveyor saw what he supposed was an oil seepage on the southeastern flank of the hills, in the southeastern part of T. 21 S., R. 17 E., or the northeastern part of T. 22 S., R. 17 E. Neither Mr. Kerr nor the senior author, who visited this locality in 1907 and made a careful examination, was able to find any traces of an oil seepage in this region, although several places were noted where mineral waters have oozed from the rocks in the rainy season. It is believed that the Kettleman Hills offer no direct surface evidence of petroliferous deposits.

GEOLOGY OF THE WELLS.

Seven or more wells have been put down in the hills and none have been successful; but owing to their position and relatively slight depth they afford no adequate test of the territory. (See pp. 241–245 for conclusions concerning future development.) Two wells, the Gibbs and Oceanic, are on the northeastern flank of the anticline; the others are on the southwestern flank. None are within the area outlined on the accompanying map as possibly productive.

The Gibbs Oil Company's well is in the eastern part of the NW. ¼ sec. 28, T. 21 S., R. 17 E., and is the farthest north of all the wells in the Kettleman Hills. It is about 1 mile east of the axis of the Coalinga anticline and starts down in beds near the top of the Etchegoin (upper Miocene) formation.

The Oceanic Oil Company's well is located on the northeastern flank of the Coalinga anticline, on one of the spur ridges running northeast from the main Kettleman Hills divide, in the NW. ¼ sec. 1, T. 22 S., R. 17 E. The well is 950 feet deep, starts in the uppermost blue-gray sands of the Etchegoin, and is said to have penetrated blue sands and shales and to have yielded large quantities of water.

The Stanislaus Oil Company's well in the NW. ¼ sec. 4, T. 22 S., R. 17 E., is located a little less than a mile southwest of the Coalinga anticline and starts in beds well up in the Etchegoin formation. It is said to have attained a depth of about 1,000 feet without encountering any oil.

The Iowa Oil Company's well is situated in the SW. ¼ sec. 4, T. 22 S., R. 17 E., not far distant from and on the same ridge as that of the Stanislaus Oil Company. The conditions in the two wells are practically the same, and the results obtained by both were similar.

The Florence Oil Company has two wells in the NW. ¼ sec. 15, T. 22 S., R. 17 E. They are on the southwest flank of the Coalinga anticline, about a mile from the axis, and near the surface penetrate strata at the bottom of the Tulare formation. They are said to have attained a depth of 720 feet and to have encountered considerable gas, but no oil.

The Esperanza Oil Company bored two wells in the SW. ¼ sec. 14, T. 22 S., R. 17 E. One was 1,100 feet deep, but was abandoned on account of water; the other reached 840 feet, when drilling was suspended. The wells lie on the southwestern flank of the anticline, over a mile from the axis, and start in the uppermost beds of the Etchegoin formation.

The well of the Stockton Oil Company in the NW. ¼ sec. 30, T. 22 S., R. 18 E., the farthest south of all the test wells in the hills, lies on the southwestern flank of the anticline about 2 miles distant from the axis. The well starts down in beds near the contact between the Etchegoin and Tulare formations, and is said to have gone to a depth of 670 feet with no results in the way of gas or oil.

CONCLUSIONS CONCERNING FUTURE DEVELOPMENT.

GENERAL STATEMENT.

The conclusions here to be discussed as to the course that future development will take in the Coalinga district are based on the belief that the asphalt oil, which forms the bulk of the product of the dis-

trict, is originally derived from the shales of the Tejon (Eocene) formation and that upon migration it collects both in the sands interbedded with these shales and in the porous portions of the overlying Miocene formations. All the conditions indicate that this belief is well founded. The purple-shale member of the Chico (Upper Cretaceous), in which the paraffin oil is supposed to have originated, was probably eroded away in the central and southern portions of the district before the deposition of the Tejon. It is, therefore, not supposed to have any bearing on the future developments except in the very northern portion of the district.

Several factors are requisite for the accumulation of the petroleum and its extraction in commercial quantities. Among these are the following, briefly stated:

(*a*) An adequate thickness of the shales of the Tejon (Eocene) to yield commercial quantities of oil.

(*b*) A cause for the migration of the oil from its source in the organic shales. This force is believed to be supplied by the tendency of oil to migrate by diffusion through certain media, such as dry shales, and this cause may be (and doubtless is in certain instances) augmented by hydrostatic pressure wherever water has come in contact with the petroleum.

(*c*) Associated porous beds occupying such a position relative to the source of the oil and to impervious barriers as to permit the petroleum to pass from the source into the final reservoir and there to be confined by impervious strata. Wet shale or clay and certain fine-grained water-impregnated sands are believed to be among the effective barriers to the migration of the oil.

(*d*) Occurrence of the accumulations far enough below the surface and distant enough from outcrops to preclude the escape of the lighter hydrocarbons, and still at depths which may be profitably reached by the drill. The areas within the lines shown on the map as bounding the possibly productive territory are those in which the top of the supposed oil zone has been calculated as possibly within a vertical distance of 4,500 feet from the surface. A depth of 4,500 feet below the surface has been arbitrarily taken as the maximum to which it is possible to drill by present methods in the region under discussion, although it is not the maximum depth of holes in California that have been drilled with a Standard rig. It may be possible to go deeper than this, but for the present this limit seems sufficient. Whether or not a well can be "profitably drilled" depends upon so many factors—such as quantity of oil produced compared with cost of drilling and price of oil—that local conditions must determine the result in each specific case.

It seems very unlikely that oil even in small amounts will be found in any of the rocks underlying the Tejon (Eocene)—that is, in the

Cretaceous or Franciscan formations (see Pl. I)—while it will very likely be found in the Tejon and in the formations immediately overlying it, whether in paying quantities depending on the factors mentioned above. In the following paragraphs it is the intention of the writers to give their personal opinion as to the probabilities of the occurrence of petroleum in those regions not yet thoroughly tested by the drill. It must be borne in mind, however, that absolute determination, by work on the surface, of the occurrence or nonoccurrence of oil in any one locality is not possible. The best that can be done is to calculate the degree of probability on the basis of surface indications and structural conditions.

TERRITORY NORTHWEST OF EASTSIDE FIELD.

The well of the T. C. Oil Company in sec. 2, T. 19 S., R. 15 E., has proved the productivity of the east flank of the Coalinga anticline almost as far north as the northern edge of the area shown on the map accompanying this report. Near there the beds bend from a strike almost due north to one N. 30° or 40° W., the dip at the same time steepening to 30° or more in secs. 34 and 35, T. 18 S., R. 15 E. A number of wells have been recently drilled near the northern edge of the territory mapped and have reached the top of the Eocene shale without obtaining petroleum in commercial quantity. The absence of any large quantity of oil is probably to be explained by the steepening of the dip, with the consequent decreasingly favorable conditions for the entrance of the oil into the Miocene sand and its accumulation there. The conclusion to be drawn is that the northern limit of productive area for the Miocene in the Eastside field has very nearly been reached. The untested possibility, however, still remains that oil may be obtained by wells sunk below the Miocene, through the Tejon, and into the paraffin-oil zone of the Chico.

REGION OF THE EASTSIDE FIELD.

Little need be said concerning the probable development in the already well-proved areas of the Eastside field, as their future may be inferred from the discussion of the geology of their wells. It should be borne in mind, however, that the lower part (and what in sec. 28 and the western part of secs. 22 and 27 is the richest part) of the oil measures has not been tested in those wells farthest down the dip, and should yield good returns for the extra cost of deepening if water is not encountered at the great depth. There is no evidence at present indicating that water exists at the base of the oil in this area. It is believed that oil in commercial quantities will never be found above the Big Blue in the Eastside field (a possible exception to this may be the St. Paul sand in section 34), so that wells

put down where the bottom of the Big Blue would be penetrated at more than 4,500 feet will probably not pay.

Two factors militate against the successful exploitation of the southwestern flank of the Coalinga anticline immediately southwest of the developed Eastside territory. These are (*a*) the steep dip (almost perpendicular in places) of the beds, which carries the oil zone rapidly downward to great depths toward the southwest, and (*b*) the more locally disturbed condition of the various beds throughout this zone of steep dip. It is believed that at least the lower part of the oil zone along this flank will be found more or less productive wherever it can be reached; but it is also believed, and this belief is strengthened by the experience of those who have drilled in the territory, that the disturbed conditions of the beds will make shutting off the water difficult or sometimes impossible, thus hindering the most successful manipulation of the wells. Toward the southeast the dips lessen in degree, and so the conditions are somewhat more favorable for successful wells.

Within the area of shale and interbedded sandstone of the uppermost member of the Chico (Upper Cretaceous), extending from Oil City northward beyond secs. 29 and 30, T. 18 S., R. 15 E., locations favorable for productive wells are believed to remain yet undeveloped. Surface indications lead to the belief that wherever in this area the sands interbedded with the purple-shale member of the Chico are porous they contain appreciable and in some places probably commercial quantities of petroleum at available depths. As the quality of the oil obtained from the Chico oil zone is usually considerably higher than that found in the Miocene, small producers in the Chico area should pay where the same production would involve a loss elsewhere. It is believed that a well site so chosen that the prospective sand would be encountered at 600 feet or more below the surface would be the most favorable for exploiting this territory. Furthermore, it is believed that productive sands in the Tejon may be tapped by wells which start in overlying formations, but predictions as to favorable locations for such tests would be unreliable, owing to the unconformable relation of the overlying beds to the Chico.

REGION OF ANTICLINE RIDGE AND GUIJARRAL HILLS.

Along the southwestern edge of the developed territory in the Eastside field the axis of the Coalinga anticline pitches southeast at about 9° at least as far southeast as the northwest corner of section 12 and probably as far as the southeast corner of the same section. From section 12 toward the southeast the anticline is believed to flatten to the region of the Guijarral Hills, where it rises toward the Kettleman Hills. The productive territory will be limited to that

portion of the anticline where the productive sands lie at a depth to be profitably reached by the drill.

In drawing conclusions as to just how far southeastward along the axis of the anticline this limit will be, two factors have to be taken into consideration—(*a*) pitch of the anticline and (*b*) thickening of the formations toward the southeast.

With regard to the first factor (*a*), evidence furnished by wells indicates a pitch of about 9°, or 1,000± feet to the mile.

With regard to the second factor (*b*), a conservative estimate indicates that at its nearest point to the surface in the northern portion of the Kettleman Hills the top of the oil-bearing zone may lie within 3,500 feet of the surface. This estimate assumes that the formations above the oil-bearing Vaqueros are considerably thicker than the same formations in the Eastside field. Just where this thickening of the beds begins it is not possible to find out, but it is believed to be toward the lower end of Anticline Ridge—that is, along the Coalinga anticline a little north of the railroad. All the evidence considered, it seems probable that the pitch indicated by the contours on the map—that is, 9°, or 1,000± feet to the mile along the anticline—is the average as far southeastward as the southeast corner of sec. 12, T. 20 S., R. 15 E., and probably much less in the region of the Guijarral Hills. Owing to the much steeper dip on the southwest flank of the anticline than on the northeast, the productive ground will be found to extend much farther away from the axis on the latter flank than on the former, as indicated by the contour map.

REGION OF THE WESTSIDE FIELD.

Owing to the rapid thinning and even entire pinching out of the Vaqueros or lower Miocene oil-bearing formation toward the western edge of the Westside field, predictions as to the exact depths at which the top of this formation will be encountered at any particular point are unusually hazardous. For this reason the top of the lowest petroliferous zone (zone B) of the Santa Margarita (?) and Jacalitos (upper Miocene) was chosen for contouring, as it extends over the whole region, although at both the north and the south ends of the field it is not commercially productive. No reasons are known at present for believing that any of the territory is unproductive in the main portion of the Westside field under which the productive measures lie at a greater depth than 500 feet. Local conditions, such as the extreme thinness of the shale or clay separating water from oil sands, may make the manipulation of certain wells more or less difficult or possibly unsuccessful, but there is no evidence of "bottom" or "edge" water in any of the wells so far drilled that condemns any of the territory generally considered as proved. On the contrary, evidence is available indicating that in many of the wells which have penetrated but a short

distance into the oil-bearing zone there are underlying and untouched sands even more productive than those already developed. It is the belief of the writers that in this field, as in the Eastside, the sands are more productive the nearer they lie to the brown shale of the Tejon. It seems worth while, therefore, in those areas where conditions are such that water could be plugged off, if encountered below the already tested productive sands, to deepen to the beds immediately overlying the brown shale. Such a procedure, however, will require great care to avoid the flooding of the upper productive beds, if water should happen to be encountered in the oil-bearing series of beds.

It is believed that considerable commercially productive territory is yet untested in the southwestern portion of the Westside field, especially north and northeast of the fault (see map, Pl. XV), which extends east and west through the middle of the SW. ¼ sec. 12, T. 21 S., R. 14 E. The extent of this productive area is believed to depend on whether the various Miocene sands are underlain by the Tejon (Eocene) formation or the Knoxville-Chico (Cretaceous). It is believed that if they are underlain by the Tejon, the beds will be found commercially productive; if by the Knoxville-Chico, except within half a mile or so of the contact between the Tejon and the Knoxville-Chico, that the oil sands will be dry or only poorly saturated. Direct evidence of the trend of the contact between the Knoxville-Chico and Tejon ends in the southwest corner of sec. 26, T. 20 S., R. 14 E., because farther south it is entirely covered by the later formations. At that locality its direction is about S. 25° E., but this strike is believed to swing eastward, so that the contact passes north of the corner of sections 1, 12, 6, and 7. The partial failure of the well in the SE. ¼ sec. 12 is believed to be due entirely to local conditions accompanying the fault north of the well, while the water in the well in the same quarter section comes from beds believed to be Knoxville-Chico.

REGION OF THE JACALITOS ANTICLINE.

The first locality south of the southwest corner of sec. 26, T. 20 S., R. 14 E., where the Tejon (Eocene) formation is definitely known is in Sulphur Spring Canyon, in the southern part of sec. 23, T. 22 S., R. 15 E. As mentioned above, there is evidence that the contact between the Knoxville-Chico and the Tejon passes north of the corner of secs. 1 and 12, T. 21 S., R. 14 E., and secs. 6 and 7, T. 21 S., R. 15 E. Just how the contact trends between this corner and the Sulphur Spring Canyon locality is not definitely known, but it is the belief of the writers, after a study of the intervening region, that the contact soon bends south after passing into the northern part of sec. 7, T. 21 S., R. 15 E., and swings around to a southwesterly trend, continuing down to Sulphur Spring Canyon, in a way somewhat similar to that

followed by the later beds, now exposed over the area. The relation of the whereabouts of this contact between the Knoxville-Chico and Tejon to the future development of the region is obvious when it is remembered that only those portions of the Miocene sands which overlie the Tejon (Eocene) are believed to be productive. It is the opinion of the writers, therefore, that the basal Miocene sands are likely to be commercially oil bearing only in the area northeast of a line which passes in a general way southwestward from the eastern part of sec. 7, T. 21 S., R. 15 E., to sec. 23, T. 22 S., R. 15 E. Southward from Alcalde Canyon the formations which overlie the oil-bearing Vaqueros thicken rapidly until, in the region of Jacalitos Creek, the Jacalitos formation (upper Miocene) alone is 3,500 feet thick, whereas in the Alcalde Canyon region it is less than 1,500 feet. This great thickening of the beds above the oil zone toward the south necessitates much deeper wells than would be required if the formations were uniform. It is estimated that at the axis of the Jacalitos anticline on Jacalitos Creek, where the supposedly productive zone approaches nearest the surface, the top of the Vaqueros is about 3,600 feet below the surface. As the axis plunges northward north of the creek and southward along the anticline from the high hill immediately south of the creek, it is obvious that the territory of possible development is very limited. The northeast flank of the Jacalitos anticline dips much more steeply than the southwest flank, so that the band of productive ground on the northeast will be much narrower than that on the southwest. Owing to the uncertainties incident to the complicated structure at the north end of the Jacalitos anticline, in sec. 18, T. 21 S., R. 15 E., and the rapid rate of thickening of the beds southward, quantitative statements concerning the depth of the oil zone below the surface at any one point will not be attempted for the region south of Alcalde Canyon. A suggestion as to the probable depth at which the oil zone lies may be gathered from the statement that it is struck at about 700 feet below sea level (1,600 feet below the surface) in the NW. ¼ sec. 18, T. 21 S., R. 15 E., and as before stated is probably some 2,800 feet below sea level (3,600 feet below the surface) on the axis of the anticline on Jacalitos Creek. This great increase in depth exists despite the fact that the axis of the anticline pitches northwest, near its northwest end as much as 15°.

REGION OF REEF RIDGE SOUTH TO DAGANY GAP.

The great monocline of Tertiary beds which flanks Reef Ridge on the east and forms the Kreyenhagen Hills is underlain by the Tejon formation from a point at least as far north as Sulphur Spring Canyon (in sec. 23, T. 22 S., R. 15 E.) to the head of Little Tar Canyon (in sec. 35, T. 23 S., R. 17 E.). Nearly throughout the extent of this

Tejon band it shows unmistakable signs of petroleum contents. Oil also seeps in many places from the Vaqueros sands overlying the Eocene, so that there is no doubt of the presence of petroleum practically throughout the length of the region under discussion. Furthermore, productive wells on Canoas Creek, in Big Tar Canyon and elsewhere (see pp. 227–232), have proved the presence of oil in commercial quantities in at least certain localities. Although the territory does not promise large individual productions the writers believe that productive wells may be put down along practically the whole strip from the region between Jacalitos and Canoas creeks to Little Tar Canyon. West of Jacalitos Creek the Tejon is apparently lacking or else is thin and insignificant; southeast of the head of Little Tar Canyon the Tejon is cut off by the Castle Mountain fault. It is therefore not likely that the productive sands extend far either northwest of Sulphur Spring Canyon or southeast of the head of Little Tar Canyon. There are indications of petroleum in the axis of the Pyramid Hills anticline, southeast of Dudley, and still farther southeastward toward the Devils Den country, so that the extension of the productive belt in a southeasterly direction from Little Tar Canyon is probably only locally affected by the fault. It is to be expected that the lighter oil will be found in the Tejon formation, but the best production will doubtless be found in the sand of the Vaqueros (lower Miocene). The production in either case will probably not be large, for the steep dip of the beds precludes the conditions necessary for great accumulations of oil. The steep dip, however, so increases the distance through which the wells may penetrate the sand that the lack of complete saturation may be partly compensated for by increased exposure of sand in the well. An item that should not be overlooked in drawing conclusions concerning this strip of territory is the probable occurrence of water in or closely associated with the oil sands. Nearly all the oil seepages in the region are accompanied by water, and many of the test wells have been abandoned on account of it, so that trouble from this source should not surprise those who may undertake to exploit the region. The depth to which the oil sands along Reef Ridge may be exploited is limited by the cost of drilling plus operation, in relation to the production and value of the oil; and also by the source of the water that is apparently associated with the oil-bearing beds—whether it is "bottom" or "edge" water. These factors are determinable only by actual test. The area outlined on the map (Pl. I) as probably productive embraces all of the territory along Reef Ridge in which it is thought that the top of the sands of the Vaqueros (lower Miocene) will be encountered at a depth less than 4,500 feet. At some localities seepages indicate that the productive zone is near the base of the formation; at other localities the evidence favors the

theory that the top will be found the most productive. All the evidence seen by the writers leads to the conclusion that the productive bodies of petroleum will not be encountered in or above the shale of the Santa Margarita (?) formation, that is, above the top of the Vaqueros (lower Miocene) zone.

REGION OF THE KETTLEMAN HILLS.

The Kettleman Hills were formed by an uplift of the sedimentary formations of this region along the Coalinga anticline. It is an interesting and important problem to consider whether this great arch, the summit of which has subsequently been in large part worn away by erosion, has brought within reach of the surface the beds which are oil bearing a few miles away. The conditions for the accumulation and preservation of oil in this broad, regular, unbroken fold would appear to be good, and the question as to the occurrence of valuable deposits resolves itself principally into two problems—(1) whether the hills are underlain by the Tejon, so that oil is probably present, and (2) whether the oil-bearing beds are brought so near the surface by the anticline as to be accessible. Direct evidence can be obtained upon either of these questions only by the drill, owing to the complete hiding of the oil-bearing formations, if such there be, by a great thickness of overlying formations; but the geologic facts observed in the hills and in other parts of the district afford indirect evidence of considerable importance favoring the theory that the necessary conditions mentioned above exist.

As regards the first condition, it may be reasonably supposed that the Tejon formation underlies the whole of the foothill and valley region within at least a few miles east and southeast of its outcrop in the hills around Pleasant Valley and along Reef Ridge. No reason is known for supposing otherwise. The Great Valley has been during long periods of geologic time a basin of depression in which deposition of sediments and subsidence has gone on, and there is evidence that during the Eocene, when the Tejon formation was being deposited in the sea that covered part of the area under discussion, the present Diablo Range was, at least in part, a belt of land that stood out with considerable relief and formed the shore line. The sea extended thence eastward, and unless a belt of land rose where the present Kettleman Hills stand the formation must have been deposited over their area. It is possible that the Coalinga anticline is an old axis of uplift that determined an area of relief in previous epochs, but it is not probable. The fact that the Cretaceous beds on Joaquin Ridge are not more disturbed than the younger ones lapping over the anticline farther east indicates that no great uplift occurred along this anticline

before the latest period of movements, during which all the formations were affected at the same time.

The same reasoning applies to the question whether the Tejon formation when once deposited over the area now occupied by the Kettleman Hills was worn away by erosion before the deposition of the younger Tertiary formations and the preservation in them of the petroleum. If no uplift of magnitude occurred it is not likely that the formation was worn away. In fact, it was probably less eroded than in the region farther west where it is now exposed, a region that was nearer the shore line and more subject to disturbances. It may therefore be assumed as a good working hypothesis that the Tejon was originally deposited and still exists beneath the formations covering the surface of the Kettleman Hills. Similarly, it is to be supposed that the whole succession of Tertiary formations is the same beneath these hills as in other parts of the district. Whether or not the Tejon is oil bearing can not be told, but being so near the extensive area in which it is petroliferous the chances are good that it is likewise so beneath these hills.

As regards the second condition, the evidence afforded by the thickness of the formations in various parts of the district must be brought to bear in order to determine at what depth the oil-bearing beds lie. The anticline exposes along its axis a low portion of the Etchegoin (uppermost Miocene) formation, and therefore the drill will have to pierce the base of this formation and the whole of the Jacalitos (early upper Miocene) and Santa Margarita (?) (upper middle Miocene) formations in order to reach the petroliferous beds of the Vaqueros (lower Miocene), provided these formations are present, as they have been assumed to be. The formations here probably bear a closer similarity in occurrence and thickness to the same formations on the western side of the syncline along the Kettleman Plain than they do to the formations in the Coalinga field. The oil probably collects, as it does along Reef Ridge, in the Vaqueros sandstone overlying the Tejon (Eocene) and is retarded from further upward migration by the compact shales of the Santa Margarita (?) formation.

The question of the thickness of each formation may be taken up separately, beginning with the exposed Etchegoin. This formation has a thickness of approximately 3,500 feet throughout the Kreyenhagen Hills, of which about 2,700 is below and 800 above the upper *Mulinia* zone. On Anticline Ridge the formation has a thickness, only roughly measurable, of about 1,700 feet. In the Kettleman Hills, inasmuch as the base is not certainly exposed, the whole formation can not be measured. The maximum thickness exposed is about 3,000 feet, in the south-central part of the hills, along that part of the anticline where it pitches in both directions. Fossil beds are there exposed which may be close to the base of the formation. If they are,

the whole formation is thinner than in the Kreyenhagen Hills. In other parts of the Kettleman Hills, where the lowest beds exposed are considerably above the base, the only means of determining the comparative thickness of the formation there and elsewhere is to compare the thickness from the summit down to the upper *Mulinia* zone, which has been correlated with the similar zone in the Kreyenhagen Hills. The position of this zone in the Kettleman Hills is shown by a line on the geologic map (Pl. I). The thickness of the formation down to it is about 1,900 to 2,000 feet in the northern part of the Kettleman Hills, but is 2,300 or 2,400 feet, if not more, in the southern half, on the southwest flank of the anticline. Here again, therefore, there is indicated a thinning of the formation in the Kettleman Hills as compared with the Kreyenhagen Hills, and this gradual decrease appears to continue on the northeast side of the Kettleman Hills. On the other hand, there is a very decided thickening southeastward from Anticline Ridge along the anticline. In conclusion, all that may be said is that the Etchegoin is at least 2,000 feet and probably more nearly 2,500 feet thick in the northern part of the Kettleman Hills, and at least 3,000 feet thick in the southern part. The thickness of it that must be pierced along the axis of the anticline in order to reach the underlying Jacalitos decreases gradually southward toward the central portion of the hills. At the south side of sec. 34, T. 21 S., R. 17 E., the upper *Mulinia* zone arches over the anticline and pitches northwestward beneath higher beds. At this point the beds are practically horizontal on the very axis of the fold, and the depth to the top of the Jacalitos is probably only a few hundred feet, possibly about 500 feet. Thence southeastward to sec. 1, T. 23 S., R. 18 E., the thickening of the formation is more than offset by the pitch of the anticline in the opposite direction, and the depth to the Jacalitos gradually decreases. Thence southward the depth is probably nowhere more than a few hundred feet and is, in general, less than in the northern part of the hills.

In both the Kreyenhagen Hills and the Coalinga field the Jacalitos formation has a thickness similar to that of the Etchegoin. The question of the accessibility of the oil sand in the Kettleman Hills hinges in large measure on the question whether this similarity in thickness between the two formations holds good there. Does the Jacalitos become thinner eastward from the Kreyenhagen Hills, as the Etchegoin seems to? It is very probable that it does.

The shale of the Santa Margarita (?) formation increases in thickness from Zapato Creek to Dagany Gap from about 200 feet to over 1,000 feet. It probably underlies the Kettleman Hills with some such thickness and with a probable similar thickening southward. There is no way of telling whether it thickens or thins eastward from the Kreyenhagen Hills, and it may therefore be assumed as constant.

On the basis of the probable conditions outlined above the combined thickness of the lower part of the Etchegoin below the upper *Mulinia* zone and of the Jacalitos and Santa Margarita (?) formations may be arbitrarily assumed to be 3,500 feet in the northern part of the Kettleman Hills and 4,500 in the south-central part. The lines on the map over the Kettleman Hills showing the possible limits of the productive territory are drawn on the basis of such an assumption.

These figures are thought to be moderate estimates. It must be borne in mind, however, that they are at best only guesses based on a balance of probabilities. If these figures are true the top of the Vaqueros formation, the supposed oil sand, lies between 3,500 and 4,000 feet immediately below the axis of the anticline throughout the hills southeast of the Big Tar Canyon-Lemoore road. Away from the axis on either side the bed begins to dip away and the depth to the Vaqueros increases rapidly. The lines bounding the supposed oil territory represent the limits of the area in which the top of the Vaqueros would be reached within 4,500 feet vertically down if the assumed thicknesses were true. On the other hand, if the formations are as thick as they are in the Kreyenhagen Hills the top of the Vaqueros would be considerably below 4,500 feet even along the axis of the anticline. In the southern part of the Kettleman Hills, for a few miles north of Avenal Gap and in the group south of it, the structure is poorly displayed. Little definite information has been obtained further than that the horizon exposed along the axis is in the lower portion of the Etchegoin. Owing to the removal of the Eocene by faulting near Little Tar Canyon and farther south it is possible that the Tejon is not present beneath the southern portion of the Kettleman Hills.

No surface indications of oil are known to exist in the Kettleman Hills, but it is not likely that oil would have been allowed to escape through the great thickness of overlying beds forming the regularly arching anticline. It is supposed also that the oil is retained by the overarching shale of the Santa Margarita (?) formation. Accumulations of a brownish substance resembling oxidized asphaltum have been observed in the Lost Hills several miles south of the southern end of the Kettleman Hills. The Lost Hills are due to an extension of the Coalinga anticline southward, and it may be that the fold pitches northward and exposes a low portion of the series, into which the possible hydrocarbons have had access. Whether or not such a supposition is founded in fact, the presence of the oxidized asphaltum in the Lost Hills favors the theory that oil will be found in the Kettleman Hills.

In conclusion, it may be said that the Kettleman Hills offer a fair chance for the discovery of oil at a depth of 3,000 to 4,500 feet

along the axis of the anticline, and that the conditions favor a well-preserved supply. The only possible means of gaining any definite knowledge of the oil-bearing formations beneath these hills is by drilling. In order to test the possibilities of the region satisfactorily wells should be sunk on the very axis of the anticline. The most favorable location for a test well would probably be between the northernmost road crossing the hills and a point 13 miles southeast of the northwest end of the hills.

AREAS CLASSIFIED AS MINERAL LAND IN THE COALINGA DISTRICT.

The following areas within the Coalinga district have been classified as mineral land, and such of these as yet belong to the Government have been withdrawn from all kinds of entry. The lands classified as mineral include all those lying between the outcrop of the base of the lowest oil-bearing beds and a line marking the limits of the area in which the uppermost productive oil zone (zone B in the Coalinga field) can be reached by a well less than 4,500 feet in depth. The lines bounding the area so included are shown on the geologic map (Pl. I). (See pp. 233–245 for relative probability of productiveness of these lands.)

List of mineral lands in Coalinga district.

T. 18 S., R. 15 E.:
W. ½ and SE. ¼ sec. 36, and secs. 35, 34, and 33.

T. 19 S., R. 14 E.:
S. ½ and NE. ¼ sec. 25, S. ½ sec. 35, and sec. 36.

T. 19 S., R. 15 E.:
Secs. 1 to 4, 8 to 17, SE. ¼ sec. 18, and secs. 19 to 36, except NW. ¼ sec. 19.

T. 19 S., R. 16 E.:
W. ½ secs. 7, 18, 19, 30, and 31.

T. 20 S., R. 14 E.:
Secs. 1 to 3, 10 to 15, 22 to 26, 35 and 36.

T. 20 S., R. 15 E.:
All of township except secs. 14, 23, 24, 25, 26, 27, 34, 35, and 36, S. ½ sec. 13, SE. ¼ sec. 15, and E. ½ sec. 22.

T. 20 S., R. 16 E.:
W. ½ secs. 6 and 7, NW. ¼ sec. 18.

T. 21 S., R. 14 E.:
Sec. 1, E. ½ sec. 2, sec. 12, and N. ½ and SE. ¼ sec. 13.

T. 21 S., R. 15 E.:
Secs. 4 to 9, W. ½ sec. 3, NW. ¼ sec. 10, S. ½ sec. 16, secs. 17, 18, 21, 22, NW. ¼ and S. ½ sec. 23, secs. 26, 27, E. ½ sec. 28, N. ½ and SE. ¼ sec. 34, and W. ½ sec. 35.

T. 21 S., R. 17 E.:
Secs. 33, 34, and NW. ¼ and S. ½ sec. 35.

T. 22 S., R. 15 E.:
SW. ¼ sec. 5, S. ½ sec. 6, secs. 7 and 8, NW. ¼ and S. ½ sec. 9, SW. ¼ sec. 10, SW. ¼ sec. 13, NW. ¼ and S. ½ sec. 14, secs. 15, 16, N. ½ sec. 17, N. ½ sec. 18, NW. ¼ sec. 22, NW. ¼ and E. ½ sec. 23, secs. 24 and 25, and NE. ¼ sec. 26.

T. 22 S., R. 16 E.:
NW. ¼ and S. ½ sec. 19, SW. ¼ sec. 20, SW. ¼ sec. 27, NW. ¼ and S. ½ sec. 28, secs. 29 and 30, N. ½ sec. 31, secs. 32 to 34, and SW. ¼ sec. 35.

T. 22 S., R. 17 E.:
NW. ¼ and S. ½ sec. 1, secs. 2 and 3, E. ½ sec. 4, NW. ¼ and E. ½ sec. 10, secs. 11 and 12, NW. ¼ and E. ½ sec. 13, and NE. ¼ sec. 14.

T. 22 S., R. 18 E.:
Sec. 7, NW. ¼ and S. ½ sec. 8, NW. ¼ and S. ½ sec. 16, secs. 17 and 18, N. ½ sec. 19, secs. 20, 21, and 22, SW. ¼ sec. 25, secs. 26, 27, and 28, NE. ¼ sec. 29, NE. ¼ sec. 33, and secs. 34, 35, and 36.

T. 23 S., R. 16 E.:
S. ½ sec. 1, secs. 2, 3, and 4, N. ½ sec. 10, secs. 11 and 12, and N. ½ sec. 13.

T. 23 S., R. 17 E.:
Sec. 7, S. ½ sec. 8, SW. ¼ sec. 15, NW. ¼ and S. ½ sec. 16, sec. 17, NW. ¼ and E. ½ sec. 18, N. ½ sec. 20, secs. 21 and 22, SW. ¼ sec. 23, SW. ¼ sec. 25, sec. 26, N. ½ and SE. ¼ sec. 27, NE. ¼ sec. 35, and sec. 36.

T. 23 S., R. 18 E.:
Secs. 1, 2, NE. ¼ sec. 3, E. ½ sec. 11, secs. 12, 13, N. ½ and SE. ¼ sec. 24, NE. ¼ sec. 25, SW. ¼ sec. 31.

T. 23 S., R. 19 E.:
W. ½ sec. 6, secs. 7, 18, and 19, W. ½ sec. 20, SW. ¼ sec. 28, sec. 29 and 30, E. ½ sec. 31, secs. 32 and 33, and SW. ¼ sec. 34.

T. 24 S., R. 18 E.:
SW. ¼ sec. 5, secs. 6 and 7, NW. ¼ and S. ½ sec. 9, SW. ¼ sec. 15, sec. 16, N. ½ and SE. ¼ sec. 17, N. ½ and SE. ¼ sec. 21, NW. ¼ and S. ½ sec. 22, sec. 27, E. ½ sec. 28, sec. 34, and W. ½ sec. 35.

T. 24 S., R. 19 E.:
Secs. 3 and 4, N. ½ and SE. ¼ sec. 5, secs. 9, 10, 15, 16, 21, and 22, SW. ¼ sec. 26, secs. 27 and 28, N. ½ and SE. ¼ sec. 33, sec. 34, and NW. ¼ and S. ½ sec. 35.

PRODUCTION AND ESTIMATED SUPPLY.

The following table of production of the Coalinga district by calendar years from 1897 to 1908 was compiled by Miss Belle Hill, under the direction of Dr. David T. Day, of the United States Geological Survey. The production for 1909 has probably been about 15,200,000 barrels, which, with the greatly increased price, has brought the value of the product for the year close to $9,000,000.

Production of petroleum in Coalinga district, 1897 to 1908.

[In barrels of 42 gallons each.]

Year.	Production.	Value.	Year.	Production.	Value.
1897	70,140		1903	2,138,058	$705,559
1898	154,000		1904	5,114,958	1,520,847
1899	439,372		1905	10,967,015	2,657,009
1900	532,000	$532,000	1906	7,991,039	1,848,300
1901	780,650	390,325	1907	8,871,723	3,091,934
1902	572,498	257,629	1908	10,386,168	5,392,916

By a rough estimate, based on the data in the hands of the writer, the amount of available oil contained before exploitation began in that part of the Coalinga district shown on the contour map

(Pl. XV) was 2,800,000,000 barrels of 42 gallons each. Of this amount about 2,000,000,000 barrels was contained in the territory west of the Coalinga syncline and 800,000,000[a] barrels east of the syncline. The total amount that has been taken from the ground up to the present time, including an estimated production of 15,200,000 barrels for 1909, approaches 63,000,000 barrels, which leaves 2,737,000,000 barrels available after 1909. At the present rate of production this supply would last over two hundred years, but with the rapid rate at which the increase in production is now taking place the time during which the supply will hold out promises to be far less. Moreover, it is not possible to state whether all the oil present can ever be obtained.

The estimate is, of course, merely an approximation. It was reached by assuming a 10 per cent impregnation of the oil sands and calculating from all the data available the probable thickness of sand under each quarter section.

TRANSPORTATION FACILITIES.

One railroad and three pipe lines constitute the transportation facilities for the oil produced in the Coalinga district.

A branch of the Southern Pacific Railroad joins Coalinga with the main line at Goshen Junction, and also with the main lines of the Atchison, Topeka and Santa Fe Railway at Hanford and Visalia. The storage tanks and loading racks for the district are at Ora station, 1½ miles northeast of Coalinga.

A 6-inch pipe line of the Coalinga Oil Transportation Company, a subsidiary of the Associated Oil Company, joins Coalinga with the seaboard at Monterey, 110 miles northwest. This line was first constructed in 1904 as an independent project and was generally known, from the name of its projector, as the Matson pipe line. The route traversed is through Alcalde Canyon, Waltham Valley, Priest Valley, Lewis Creek, and the Salinas Valley. Several pumping stations are situated along the line between Coalinga and Monterey, the main station being in the SW. ¼ sec. 18, T. 20 S., R. 15 E.; it is joined by minor lines with various parts of the Eastside and Westside fields.

An 8-inch branch pipe line 28 miles long joins the Coalinga field with the main Kern River and Point Richmond line of the Standard Oil Company at Mendota. The total distance from Coalinga to tide water by this line is 198 miles. The main pumping station of this company for the Coalinga field is in the NW. ¼ sec. 36, T. 19 S., R. 15 E.

The Producers' Transportation Company, a subsidiary of the Union Oil Company, is now constructing an 8-inch line between

[a] Recent developments in the Eastside field have tended to reduce the estimate of the probable productive area so much that the original estimate of 875,000,000 barrels for this field has been cut to 800,000,000 barrels.

Coalinga and the Antelope Valley, 45 miles to the southeast, where it will join the main 8-inch line to the coast at Port Harford. This is part of a system of lines which are to join the Kern River, Sunset, Midway, and McKittrick districts with tide water. The distance from Coalinga to Port Harford by this route is a little over 100 miles, the line traversing Polonio, Cholame, and Cuesta passes and passing Dudley, Cholame, Santa Margarita, and San Luis Obispo.

The Associated Oil Company is now laying a new 8-inch line from Sunset through the Midway, McKittrick, and Coalinga districts via Mendota to tide water at San Francisco Bay. This line will be completed early in 1910.

Numerous local lines transport the oil from various parts of the field to the shipping stations. Among these lines are those of the Union Oil Company from sec. 13, T. 20 S., R. 14 E., to Ora; the California Oilfields (Limited), from the Eastside field to Ora; the Coalinga Oil Company, from the Oil City field to Ora; the Westside line, from the Westside field to Ora; and the Associated Oil Company, from the Westside field to Ora.

OIL COMPANIES AND OIL WELLS IN THE COALINGA DISTRICT.

The following is a practically complete list of all of the oil companies and the wells which they had drilled or were drilling in the Coalinga district up to October 15, 1909. The locations of the wells are indicated wherever known, and the elevations of most wells are given, having been obtained by instrument survey by E. P. Davis, topographer. A table following this one shows the names of companies and the number of wells in the Coalinga district April 30, 1909.

Oil companies and oil wells in Coalinga district.

[Location by Mount Diablo meridian.]

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Ætna. (See California Oilfields, Ltd.)				
Ajax		[a]1	SW. ¼ sec. 32, T. 19 S., R. 15 E.	
Aladdin. (See Coalinga Aladdin.)				
American Petroleum		1	SW. ¼ sec. 18, T. 20 S., R. 15 E.	
Do		2	....do	
Do		3	....do	
Do		4	....do	
Do		5	NW. ¼ sec. 18, T. 20 S., R. 15 E.	
Do		6	....do	
Do		7	....do	
Do		8	....do	
Do		[b]32	....do	
Do		1	SW. ¼ sec. 19, T. 20 S., R. 15 E.	

[a] Abandoned.

[b] Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
American Petroleum		2	SW. ¼ sec. 19, T. 20 S., R. 15 E.	
Do		3	do	
Do		4	do	
Do		a 5	do	
Do		a 8	do	
Do		a 12	do	
Do		a 16	do	
Do		1	SW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	NW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		6	do	
Do		a 7	SW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		a 13	do	
Do	North Thirty	a 1	NW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do	do	a 2	do	
Do	do	a 3	do	
Do	do	a 4	do	
Amy		1	SE. ¼ sec. 6, T. 21 S., R. 15 E.	800
Angelus. (See Traders.)				
Arica	Porter & Scribner	1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	873
Do	do	b 2	do	868
Do	do	3	do	848
Do	do	4	do	
Do	do	5	do	
Do	do	6	NE. ¼ sec. 7, T. 20 S., R. 15 E.	
Do	do	7	do	
Arizona Petroleum	East Puente	1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Do	do	2	do	
Do	do	3	do	
Do	do	a 4	do	
Associated		1	SW. ¼ sec. 22, T. 19 S., R. 15 E.	1,255
Do		2	do	1,235
Do		3	do	1,223
Do		4	do	1,208
Do		5	do	1,144
Do	Old No. 1	1A	SE. ¼ sec. 36, T. 20 S., R. 14 E.	835
Do	Old No. 2	1B	do	875
Do	Old No. 4	1C	do	834
Do	Old No. 3	2A	do	831
Do	Old No. 5	3A	do	828
Do		4A	do	
Do		4B	do	
Do		4C	do	
Do		5A	NE. ¼ sec. 36, T. 20 S., R. 14 E.	
Do		5B	do	
Do		5C	do	
Do	Old No. 11	6A	do	
Do		6B	do	
Do		6C	do	
Do	Old No. 13	7A	do	
Do		7B	do	
Do		7C	do	
Do		7D	do	
Do	Old No. 15	8A	do	
Do	Old No. 45	8B	do	
Do	Old No. 43	8C	do	
Do	Old No. 41	8D	do	
Do	Old No. 17	9A	do	
Do	Old No. 19	9B	do	
Do	Old No. 21	9C	do	800
Do	Old No. 23	9D	do	814
Do	Old No. 39	8E	NW. ¼ sec. 36, T. 20 S., R. 14 E.	
Do	Old No. 37	8F	do	
Do	Old No. 25	9E	do	828
Do	Old No. 27	9F	do	843
Do	Old No. 29	9G	do	858
Do	Old No. 31	9H	do	
Do	Old No. 32	9I	do	
Avenal Land and Oil		b 2	Sec. 18, T. 23 S., R. 17 E.	
Avon. (See California Oilfields, Ltd.)				
B. and B	Brix and Buntin	1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	848
Do		2	do	852
Do		3	do	

a Drilling. b Abandoned.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
B. and B	Brix and Buntin	4	SE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		5	do	
Do		6	do	
Do		8	do	
Baby King		a 1	NE. ¼ sec. 11, T. 22 S., R. 16 E.	
Badger State		a 1	Sec. 1, T. 21 S., R. 14 E.	
Best Yet			NW. ¼ sec. 13, T. 21 S., R. 15 E.	
Black Mountain		a 2	NW. ¼ sec. 22, T. 22 S., R. 16 E.	
Blair		b 1	NW. ¼ sec. 14, T. 21 S., R. 15 E.	
Blue Diamond. (See McQuigg & Wren.)				
Blue Goose		a 1	NE. ¼ sec. 29, T. 19 S., R. 15 E.	
Blue Moon		1	SE. ¼ sec., 6 T. 19 S., R. 15 E.	847
Bonanza King		a 1	SW. ¼ sec. 10, T. 19 S., R. 15 E.	
Boston and California		b 1	SE. ¼ sec. 24, T. 19 S., R. 15 E.	
Boychester			NE. ¼ sec. 13, T. 21 S., R. 15 E.	
British Consolidated	California Diamond No. 5.	b 1	SW. ¼ sec. 12, T. 19 S., R. 15 E.	802
Do	California Monarch No. 1.	1	SE. ¼ sec. 29, T. 19 S., R. 15 E.	864
Do	California Monarch No. 2.	b 2	do	869
Do	California-New York	1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	834
Do	do	2	do	846
Do	do	3	do	839
Do	do	4	do	835
Do	do	5	do	843
Do	do	6	do	
Do	California Diamond Buntin No. 1.	a 1	NW. ¼ sec. 24, T. 21 S., R. 15 E.	
Buena Vista. (See Kettleman Hills.)				
Buntin. (See British Consolidated.)				
Caledonian		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	882
Do		a 2	do	880
Do		3	do	847
Do		4	do	842
California and New York (See British Consolidated.)				
California Diamond. (See British Consolidated; also W. M. & M.)				
California Monarch. (See British Consolidated.)				
California Oil and Gas		a 1	SE. ¼ sec. 19, T. 19 S., R. 15 E.	
Do	T. C	1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	759
Do	do	b 2	do	
California Oilfields, Ltd	Avon, No. 1	1	SW. ¼ sec. 14, T. 19 S., R. 15 E.	1,101
Do	Avon, No. 2	2	NW. ¼ sec. 14, T. 19 S., R. 15 E.	1,035
Do	Kaweah, No. 1	3	NE. ¼ sec. 14, T. 19 S., R. 15 E.	877
Do	Kaweah, No. 2	4	SE. ¼ sec. 14, T. 19 S., R. 15 E.	950
Do	Avon, No. 3	5	NW. ¼ sec. 14, T. 19 S., R. 15 E.	856
Do		1	SE. ¼ sec. 21, T. 19 S., R. 15 E.	1,451
Do		2	do	1,322
Do		3	do	1,444
Do		4	do	1,340
Do		5	do	1,429
Do		6	do	1,461
Do		7	do	1,377
Do		8	do	1,393
Do		9	NE. ¼ sec. 21, T. 19 S., R. 15 E.	1,368
Do	Arline, No. 1	1	SW. ¼ sec. 26, T. 19 S., R. 15 E.	1,007
Do	Arline, No. 2	2	NW. ¼ sec. 26, T. 19 S., R. 15 E.	1,028
Do	Northeastern, No. 1	3	NE. ¼ sec. 26, T. 19 S., R. 15 E.	956
Do		4	SW. ¼ sec. 26, T. 19 S., R. 15 E.	
Do	Section Ten	1	NE. ¼ sec. 10, T. 19 S., R. 15 E.	
Do	do	2	SE. ¼ sec. 10, T. 19 S., R. 15 E.	
Do	do	3	NE. ¼ sec. 10, T. 19 S., R. 15 E.	
Do		1	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,387
Do		2	do	1,363
Do		3	do	1,349
Do		4	do	1,353
Do		5	do	1,380
Do		6	do	1,214
Do		7	do	1,331

[a] Abandoned. [b] Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
California Oilfields, Ltd.		8	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,305
Do.		9	do.	a 1,319
Do.		10	do.	a 1,080
Do.		11	do.	a 1,340
Do.		12	SW. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,284
Do.		13	NW. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,130
Do.		14	do.	a 1,270
Do.		15	do.	a 1,225
Do.		16	do.	a 1,229
Do.		17	do.	1,332
Do.		18	do.	1,340
Do.		19	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,256
Do.		20	do.	1,307
Do.		21	do.	1,117
Do.		22	do.	1,144
Do.		23	SE. ¼ sec. 27, T. 19 S., R. 15 E.	1,105
Do.		24	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,238
Do.		25	do.	1,246
Do.		26	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,273
Do.		b 27	SE. ¼ sec. 27, T. 19 S., R. 15 E.	983
Do.		28	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,257
Do.		29	do.	1,188
Do.		30	do.	a 1,275
Do.		31	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,194
Do.		32	do.	1,166
Do.		33	do.	1,260
Do.		b 34	NE. ¼ sec. 27, T. 19 S., R. 15 E.	1,022
Do.		35	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,168
Do.		36	NE. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,180
Do.		37	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,271
Do.		38	do.	1,234
Do.		39	do.	1,225
Do.		41	NW. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,350
Do.		42	NW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		43	SW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		44	do.	
Do.		45	do.	
Do.		46	NW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		47	do.	
Do.		48	do.	
Do.		49	NE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		50	SW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		51	SE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		52	NW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		53	NE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		54	SE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		b 55	do.	
Do.		b 56	do.	
Do.		b 57	do.	
Do.		b 58	do.	
Do.		b 59	do.	
Do.		b 60	do.	
Do.		61	NE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do.		62	do.	
Do.		b 63	do.	
Do.		b 64	do.	
Do.		1	SW. ¼ sec. 29, T. 19 S., R. 15 E.	1,217
Do.		2	do.	1,256
Do.	Ætna, No. 1	1	SE. ¼ sec. 30, T. 19 S., R. 15 E.	1,225
Do.	Westmoreland, No. 1	1	NW. ¼ sec. 34, T. 19 S., R. 15 E.	1,118
Do.	Forty, No 1	2	NE. ¼ sec. 34, T. 19 S., R. 15 E.	1,096
Do.	Westmoreland, No. 2	3	NW. ¼ sec. 34, T. 19 S., R. 15 E.	1,109
Do.	Missouri Coalinga, No. 1	4	do.	1,150
Do.	Westmoreland, No. 3	5	do.	1,085
Do.	Forty, No. 3	6	NE. ¼ sec. 34, T. 19 S., R. 15 E.	1,061
Do.	Pittsburg-Coalinga, No. 1.	7	do.	1,080
Call		1	NW. ¼ sec. 32, T. 19 S., R. 15 E.	1,213
Do.		2	do.	
Do.		b 3	do.	
Camwell	Octave, No. 1	1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	1,212
Do.	Octave, No. 2	2	do.	1,208
Do.		3	do.	
Do.		b 4	do.	
Do.		b 5	do.	

a Approximate.

b Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Call		1	NW. ¼ sec. 22, T. 19 S., R. 15 E.	1,213
Caribou Oil Mining		1	SW. ¼ sec. 22, T. 19 S., R. 15 E.	1,300
Do		2	....do	1,338
Do		3	....do	1,357
Do		4	....do	1,417
Do		5	....do	1,391
Do		6	....do	1,420
Do		7	....do	1,257
Do		8	....do	1,224
Do		9	....do	1,204
Do		10	....do	1,233
Do		11	....do	1,313
Do		12	....do	1,116
Do		13	....do	1,300
Carmelita		[a] 1	SE. ¼ sec. 3, T. 20 S., R. 15 E.	.....
Circle		1	NE. ¼ sec. 35, T. 20 S., R. 14 E.	.....
Claremont		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	[b] 810
Do		2	....do	[b] 814
Do		3	....do	[b] 800
Do		4	....do	782
Do		5	....do	.....
Do		6	....do	.....
Do		10	....do	.....
Do		11	....do	.....
Do		12	....do	.....
Do		13	....do	.....
Do		14	....do	.....
Do		1	NE. ¼ sec. 4, T. 20 S., R. 15 E.	1,022
Coalinga	Producers and Consumers, No. 1.	[a] 1	NW. ¼ sec. 20, T. 19 S., R. 15 E.	[b] 1,406
Do		2	....do	1,453
Do	Producers and Consumers, No. 2.	[a] 2	....do	[b] 1,410
Do		3	....do	1,453
Do	Producers and Consumers, No. 3.	3	....do	1,421
Do		4	....do	1,449
Do		5	....do	1,465
Do		6	....do	1,435
Do		7	....do	1,579
Do		9	....do	1,499
Coalinga Aladdin	Aladdin	1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	787
Coalinga Aztec	E. W. Risley	[c] 1	SE. ¼ sec. 31, T. 19 S., R. 15 E.	.....
Coalinga California		[c] 1	NW. ¼ sec. 8, T. 20 S., R. 15 E.	.....
Coalinga Crystal	Z. L. Phelps		NW. ¼ sec. 12, T. 21 S., R. 14 E.	.....
Coalinga Gem			E. ½ sec. 18, T. 21 S., R. 15 E.	.....
Coalinga Great Western	West Coalinga	[d] 1	NE. ¼ sec. 12, T. 21 S., R. 14 E.	.....
Do		2	....do	.....
Coalinga Homestake	Cawder	1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	.....
Do	....do	2	....do	.....
Do		[c] 3	....do	.....
Coalinga Mohawk		1	NW. ¼ sec. 12, T. 20 S., R. 15 E.	[b] 850
Coalinga National		[c] 1	N. ½ sec. 8, T. 20 S., R. 15 E	.....
Coalinga Pacific		1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	880
Do		2	....do	883
Do		3	....do	910
Do		4	....do	873
Do		5	....do	.....
Coalinga-Peerless		1	NW. ¼ sec. 22, T. 19 S., R. 15 E.	1,362
Do		2	....do	1,284
Do		3	....do	1,363
Do		4	....do	1,360
Do		5	....do	1,260
Do		6	....do	1,259
Do		7	....do	1,261
Do		8	....do	1,212
Do		9	....do	1,224
Do		10	....do	1,168
Do		11	....do	1,259
Do		12	....do	1,150
Do		13	....do	.....
Do		14	....do	.....
Do		15	....do	.....
Do		[c] 16	....do	.....
Coalinga Petroleum		1	NE. ¼ sec. 14, T. 20 S., R. 14 E.	870
Do		2	....do	878

[a] Abandoned. [b] Approximate. [c] Drilling. [d] Water well.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Coalinga Petroleum		3	NE. ¼ sec. 14, T. 20 S., R. 14 E.	887
Do		4	....do	883
Do		5	....do	
Do		6	....do	
Do		7	....do	
Do		[a] 8	....do	
Coalinga Southern. (See Yellowstone.)				
Coalinga South Pole		[a] 1	SE. ¼ sec. 18, T. 21 S., R. 15 E.	
Coalinga Unity	Shawmut	[a] 1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	
Coalinga Western		1	NE. ¼ sec. 23, T. 20 S., R. 14 E.	968
Do		2	....do	977
Do		3	....do	960
Do		4	....do	910
Do		5	....do	887
Do		6	....do	960
Do		7	....do	869
Do		8	....do	
Coast Range		1	SW. ¼ sec. 17, T. 19 S., R. 15 E.	[b] 1,450
Do		2	....do	[b] 1,450
Do		3	....do	1,451
Do		4	SE. ¼ sec. 17, T. 19 S., R. 15 E.	1,469
Do		5	SW. ¼ sec. 17, T. 19 S., R. 15 E.	1,485
Do		6	....do	1,533
Commercial		[c] 2	SE. ¼ sec. 12, T. 21 S., R. 14 E.	
Commercial Petroleum		1	....do	869
Do		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,236
Do		2	....do	1,243
Do		3	....do	1,242
Do		4	....do	1,253
Do		5	....do	1,244
Do		6	....do	1,241
Do		7	....do	1,259
Do		8	....do	1,254
Do		9	....do	1,239
Do		10	....do	1,220
Do		[a] 11	....do	
Do		12	....do	
Confidence		2	NW. ¼ sec. 31, T. 19 S., R. 15 E.	[b] 1,280
Do		4	....do	[b] 1,275
Do		5	SW. ¼ sec. 31, T. 19 S., R. 15 E.	1,101
Do		6	NW. ¼ sec. 31, T. 19 S., R. 15 E.	1,240
Do		7	....do	1,236
Do		8	SW. ¼ sec. 31, T. 19 S., R. 15 E.	1,251
Do		9	....do	1,190
Do		10	....do	1,227
Do		11	....do	1,171
Do	K and C, No. 5	12	....do	1,203
Do		[a] 13	....do	1,205
Do		[a] 14	....do	1,243
Do		[d]	....do	
Consolidated Oil and Development.		[c] 1	NE. ¼ sec. 10, T. 23 S., R. 16 E.	
Consolidated	Manchester	[a] 1	NW. ¼ sec. 18, T. 21 S., R. 15 E.	
Crescent		[c] 1	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Cypress	R. H. Herron, No. 1	1	SE. ¼ sec. 1, T. 20 S., R. 14 E.	917
Do	R. H. Herron, No. 2	2	....do	911
Do	R. H. Herron, No. 3	3	....do	941
Do	R. H. Herron, No. 4	4	....do	738
De Lux		1	SE. ¼ sec. 6, T. 21 S., R. 15 E.	777
Domengine			NE. ¼ sec. 35, T. 18 S., R. 15 E.	
El Capitan (now Kern Trading and Oil).		2	NW. ¼ sec. 31, T. 19 S., R. 15 E.	
El Cerrito		[a] 1	NW. ¼ sec. 14, T. 23 S., R. 17 E.	
Elk		[c] 1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	
Ellis. (See W. M. & M.)				
Empire	J. A. McClurg	[a] 1	NE. ¼ sec. 32, T. 19 S., R. 15 E.	
Esperanza Oil and Gas		1	SW. ¼ sec. 6, T. 20 S., R. 15 E.	997
Do		2	....do	989
Do		3	....do	972
Do		4	....do	956
Do		5	....do	981
Do		6	....do	943
Do		7	....do	936
Do		8	....do	916
Do		[c] 2	SW. ¼ sec. 14, T. 22 S., R. 17 E.	
Do		9	SW. ¼ sec. 6, T. 20 S., R. 15 E.	

[a] Drilling. [b] Approximate. [c] Abandoned. [d] Water well.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Esperanza Oil and Gas		10	SW. ¼ sec. 6, T. 20 S., R. 15 E.	
Do		11	do	
Esperanza Land and Oil		[c]1	Sec. 30, T. 21 S., R. 15 E.	
Euclid. (See Traders.)				
Florence		[b]2	NW. ¼ sec. 15, T. 22 S., R. 17 E.	
Forty. (See California Oilfields, Ltd.)				
Fresno-San Francisco		1	NE. ¼ sec. 1, T. 20 S., R. 14 E.	1,140
Do		2	do	1,128
Do		3	do	1,072
Do		4	do	1,114
Do		5	do	
Do		6	do	
Do		7	do	
Gibbs		[b]1	NW. ¼ sec. 28, T. 21 S., R. 17 E.	
Golden Crest	Kreyenhagen, No. 1	[c]1	NE. ¼ sec. 12, T. 22 S., R. 15 E.	
Golden State. (Now California Oilfields, Ltd.)		[b]1	SE. ¼ sec. 30, T. 19 S., R. 15 E.	
Good Luck	Octave	1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	
Great Western		[b]1	SW. ¼ sec. 26, T. 19 S., R. 15 E.	
Gulberson, S. A., jr	Elgar Adams		E. ½ sec. 14, T. 20 S., R. 14 E.	
Guthrey		1	NE. ¼ sec. 21, T. 19 S., R. 15 E.	1,267
Do		2	do	1,263
Do		3	do	1,227
Do		3	do	1,242
Guthrey. (See Sauer Dough.)				
Hawkeye State		[b]2	Sec. 6, T. 21? S., R. 15? E.	
Henshaw. (See Sunnyside.)				
Herron, R. H. (See Cypress.)				
Highland (Hearst estate)	New York, Nos. 1 and 2	[b]2	SW. ¼ sec. 20, T. 19 S., R. 15 E.	
Home		1	NE. ¼ sec. 20, T. 19 S., R. 15 E.	[c]1,490
Do		2	do	1,491
Do		3	do	1,567
Do		4	do	1,598
Do		5	do	1,597
Do		6	do	1,519
Do		7	do	1,585
Do		8	do	1,593
Inca		1	NW. ¼ sec. 24, T. 20 S., R. 14 E.	801
Do		2	do	811
Do		3	do	816
Do		4	do	799
Do		5	do	814
Do		6	do	805
Do		7	do	797
Do		8	do	805
Do		9	do	814
Do		10	do	818
Do		11	do	834
Do		12	do	870
Imperial		[b]1	NE. ¼ sec. 2, T. 19 S., R. 15 E.	
Do		[b]2	do	
Do		[b]3	do	
Do		[b]4	do	
Independence. (See Standard.)				
Independent		[b]1	NE. ¼ sec. 17, T. 19 S., R. 15 E.	
Investment		[b]1	SE. ¼ sec. 16, T. 19 S., R. 15 E.	
Iowa		[b]1	SW. ¼ sec. 4, T. 22 S., R. 17 E.	
Jacalitos		[a]1	Sec. 30, T. 21 S., R. 15 E.	
Jefferson		1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	802
Do		[a]2	do	832
K. and C. (See Confidence.)				
Kaweah. (See California Oilfields, Ltd.)				
Kern Trading and Oil		[a]22	SE. ¼ sec. 3, T. 19 S., R. 15 E.	
Do		[a]25	do	
Do		1	NW. ¼ sec. 11, T. 19 S., R. 15 E.	
Do		4	do	
Do		1	NW. ¼ sec. 31, T. 19 S., R. 15 E.	[c]1,210
Do		2	do	1,234
Do		3	do	1,222
Do		[b]5	do	
Do		[b]6	do	
Do		7	do	1,270
Do		8	do	1,242

[a] Drilling. [b] Abandoned. [c] Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Kern Trading and Oil (K. T. & O.).		1	NW. ¼ sec. 35, T. 19 S., R. 15 E.	
Do		a 2	....do	
Do		a 11	SW. ¼ sec. 35, T. 19 S., R. 15 E.	
Do		a 13	....do	
Do		a 15	....do	
Do		1	SW. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		2	....do	
Do		3	....do	
Do		5	....do	
Do		6	....do	
Do		7	....do	
Do		8	SE. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		9	....do	
Do		10	....do	
Do		11	....do	
Do		12	....do	
Do		13	....do	
Do		14	....do	
Do		a 16	....do	
Do		a 20	....do	
Do		a 22	....do	
Do		1	SW. ¼ sec. 25, T. 20 S., R. 14 E.	811
Do		2	....do	803
Do		3	....do	
Do		4	....do	
Do		9	NW. ¼ sec. 25, T. 20 S., R. 14 E.	
Do		10	....do	
Do		11	....do	
Do		15	....do	
Do		18	....do	
Do		20	....do	
Do		22	....do	
Do		24	....do	
Do		25	NE. ¼ sec. 25, T. 20 S., R. 14 E.	
Do		35	....do	
Do		37	....do	
Do		39	....do	
Do		41	....do	
Do		43	....do	
Do		45	....do	
Do		47	SE. ¼ sec. 25, T. 20 S., R. 14 E.	
Do		49	....do	
Do		51	....do	
Do		53	....do	
Do		54	....do	
Do		a 1	NW. ¼ sec. 19, T. 20 S., R. 15 E.	
Do		a 3	....do	
Do		a 5	....do	
Do		a 1	NW. ¼ sec. 31, T. 20 S., R. 15 E.	
Keystone		b 1	NW. ¼ sec. 32, T. 19 S., R. 15 E.	
Kings County		b 1	NE. ¼ sec. 3, T. 23 S., R. 16 E.	
Do		b 1	SW. ¼ sec. 3, T. 23 S., R. 16 E.	
Kreyenhagen		b 2	SE. ¼ sec. 32, T. 22 S., R. 16 E.	
Kreyenhagen. (See Golden Crest.)				
Lorene		b 1	NW. ¼ sec. 12, T. 19 S., R. 15 E.	c 825
Los Angeles-Coalinga Oil Syndicate.		a 1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	
Lucile		1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	770
Do		2	....do	761
Do		3	....do	787
Do		a 4	....do	
Maguire			NW. ¼ sec. 30, T. 20 S., R. 15 E.	
McCreary. (See California Oilfields, Ltd.)				
Maine State		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,256
Do		b 2	....do	c 1,300
Do		3	....do	1,274
Do		4	....do	1,237
Do		5	....do	c 1,250
Do		6	SE. ¼ sec. 31, T. 19 S., R. 15 E.	1,089
Do		7	....do	1,119
Do		8	....do	1,119
Do		9	....do	1,154
Manchester		b 1	SW. ¼ sec. 18, T. 21 S., R. 15 E.	900
Marengo. (See Traders.)				

a Drilling. b Abandoned. c Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Marion	St. Clair	a 1	SW. ¼ sec. 6, T. 21 S., R. 15 E.	
McQuigg & Wren	Blue Diamond No. 1		NE. ¼ sec. 14, T. 20 S., R. 14 E.	920
Do		1	do	
May Brothers		b 1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Mercantile Crude		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,097
Do		2	do	c 1,120
Do		3	do	1,006
Do		4	do	1,002
Do		5	do	
Michigan Oil and Development.		a 1	Sec. 177, T. 19. S., R. 13 E	
Minnesota (now Southern Pacific R. R.)		b 2	NE. ¼ sec. 33, T. 19 S., R. 15 E.	
Missouri-Coalinga. (See California Oilfields, Ltd.)				
M., K. and T.		1	SW. ¼ sec. 8, T. 20 S., R. 15 E.	868
Do		2	do	866
Montjack		b 1	NW. ¼ sec. 22, T. 19 S., R. 15 E.	
Mount Hamilton Land and Oil.		b 1	SE. ¼ sec. 14, T. 21 S., R. 14 E.	1,002
Muriel	St. Francis	1	SW. ¼ sec. 6, T. 21 S., R. 15 E.	939
Mutual		b 1	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Nathan. (See Arica.)				
Netherlands	Valley Slope	1	SE. ¼ sec. 26, T. 21 S., R. 14 E.	
Do		a 2	do	
Nevada Petroleum		a 1	NE. ¼ sec. 18, T. 20 S., R. 15 E.	
Do		a 1	W. ½ sec. 20, T. 20 S., R. 15 E.	
Do		1	SE. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		a 2	do	
Do		a 4	do	
Do		a 8	NE. ¼ sec. 30, T. 20 S., R. 15 E.	
New Era		1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		2	do	
New Home. (See St. Elmo.)				
New San Francisco Crude		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,135
Do		2	do	1,105
Do		3	do	1,068
Do		4	do	1,098
Do		5	do	1,079
Do		6	do	
Do		7	do	
Do		8	do	
New York. (See Highland.)				
Norse. (See Traders.)				
Northeastern. (See California Oilfields, Ltd.)				
Oceanic		b 1	NW. ¼ sec. 1, T. 22 S., R. 17 E.	
Octave. (See Camwell.)				
Oil City Petroleum. (See Standard.)				
Old Keystone		b 1	SE. ¼ sec. 8, T. 19 S., R. 15 E.	
Oyama. (See California Oilfields, Ltd.)				
Ozark		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	c 850
Do		2	do	c 845
Do		3	do	
Do		4	do	
Peerless Consolidated		b 1	NE. ¼ sec. 10, T. 20 S., R. 15 E.	815
Piedmont		a 1	Sec. 24, T. 20 S., R. 14 E.	
Pennsylvania Coalinga		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	1,056
Do		2	SE. ¼ sec. 24, T. 20 S., R. 14 E.	976
Do		3	do	923
Do		4	do	975
Do		5	do	
Do		6	do	
Philadelphia and San Francisco.		1	SE. ¼ sec. 36, T. 19 S., R. 14 E.	1,121
Do		2	do	
Do		3	do	1,107
Phoenix		b 3	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Pilot		1	SW. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	do	
Pittsburg		1	SW. ¼ sec. 24, T. 19 S., R. 15 E.	830
Pittsburg-Coalinga. (See California Oilfields, Ltd.)				

a Drilling. b Abandoned. c Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Porter & Scribner. (See Arica.)				
Premier		1	SE. ¼ sec. 24, T. 20 S., R. 14 E.	[a] 790
Do		2	do	
Producers and Consumers. (See Coalinga.)				
Queen	Coalinga Banner	1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Do	do	2	do	
Record		1	SE. ¼ sec. 22, T. 19 S., R. 15 E.	1,189
Do		2	do	1,177
Do		3	do	
Do		4	do	
Do		[b] 5	do	
Do		[b] 6	do	
Do		[b] 7	do	
Red top		[b] 1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	812
Riverside. (Near Alcalde.)				
Roanoke		[c] 1	SE. ¼ sec. 36, T. 19 S., R. 14 E.	
Rock		[c] 1	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
St. Clair		1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		5	SW. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		6	do	
St. Elmo	New Home	1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Do	do	2	do	
Do	do	3	do	
Do	do	4	do	
Do	do	5	do	
St. Francis. (See Muriel.)				
St. Lawrence		[c] 1	NE. ¼ sec. 12, T. 23 S., R. 16 E.	
St. Paul-Fresno		1	NE. ¼ sec. 23, T. 20 S., R. 14 E.	[a] 950
Do		2	do	970
Do		3	do	920
Do		4	do	906
Do		5	do	910
Do		6	do	
Do		7	do	
Do		8	do	
Do		9	do	
Santa Clara		[c] 1	SW. ¼ sec. 30, T. 19 S., R. 15 E.	
Sauer Dough		1	do	1,435
Do		2	do	1,304
Do		3	do	1,313
Do		4	do	1,388
Do		5	do	1,435
Do		6	do	1,283
Do		7	do	1,340
Do		8	do	
Do		9	do	
Do		10	do	
Do	Guthrey	1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	
Section One	Coalinga Zenith		Sec. 35, T. 20 S., R. 14 E.	
Do	do		Sec. 1, T. 21 S., R. 14 E.	
Section Seven		1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	911
Do		2	do	915
Do		3	do	916
Do		4	do	908
Do		[b] 5	do	[a] 880
Do		[b] 6	do	
Section Six. (See Jefferson.)				
Section Ten		[c] 1	SW. ¼ sec. 10, T. 19 S., R. 15 E.	
Selma. (See Section One.)				
Seneca		1	NW. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	do	
Shawmut		1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	878
Do		2	do	882
Do		3	do	892
Do		4	do	[a] 910
Do		5	do	879
Shreeve		1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	853
Silver Tip		1	SE. ¼ sec. 6, T. 21 S., R. 15 E.	822
Do		[b] 2	do	
Smith & Porter	Summit	[c] 1	SW. ¼ sec. 12, T. 21 S., R. 14 E.	
Southeastern		[b] 1	NW. ¼ sec. 18, T. 20 S., R. 16 E.	

[a] Approximate. [b] Drilling. [c] Abandoned.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Spinks	Shawmut, No. 6	1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do	Shawmut, No. 7	2	do	
Do	Shawmut, No. 8	3	do	
Standard	Independence, No. 1	1	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,497
Do	Independence, No. 3	3	do	1,440
Do	Independence, No. 4	4	do	1,374
Do	Independence, No. 5	5	do	a 1,450
Do	Independence, No. 6	6	do	1,444
Do	Independence, No. 7	7	do	1,458
Do	Independence, No. 8	8	do	1,484
Do	Independence, No. 9	9	do	1,536
Do	Independence, No. 10	10	do	1,538
Do	Oil City Petroleum, No. 1.	11	SE. ¼ sec. 28, T. 19 S., R. 15 E.	1,371
Do	Oil City Petroleum, No. 2.	12	do	1,404
Do	Oil City Petroleum, No. 3.	13	do	1,372
Do	Oil City Petroleum, No. 4.	14	do	1,376
Do	Oil City Petroleum, No. 5.	15	do	1,448
Do	Oil City Petroleum, No. 6.	16	do	1,373
Do	Oil City Petroleum, No. 7.	17	do	1,348
Do	Oil City Petroleum, No. 8.	18	do	1,340
Do	Oil City Petroleum, No. 9.	19	do	1,361
Do	Oil City Petroleum, No. 10.	20	do	1,321
Do	Oil City Petroleum, No. 11	21	do	1,323
Do	Oil City Petroleum, No. 12.	22	do	1,262
Do	Oil City Petroleum, No. 13.	23	do	1,211
Do	Oil City Petroleum, No. 14.	24	do	1,253
Do	Oil City Petroleum, No. 15.	25	do	1,275
Do	Twenty-eight, No. 14	26	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,314
Do	Twenty-eight, No. 13	27	do	1,395
Do	Twenty-eight, No. 12	28	do	1,385
Do	Twenty-eight, No. 10	29	do	1,241
Do	Twenty-eight, No. 11	30	do	1,378
Do	Twenty-eight, No. 9	31	do	1,420
Do	Twenty-eight, No. 8	32	do	1,402
Do	Twenty-eight, No. 6	33	do	1,256
Do	Twenty-eight, No. 5	34	do	1,342
Do	Twenty-eight, No. 4	35	do	1,342
Do	Twenty-eight, No. 1	36	do	a 1,380
Do	Twenty-eight, No. 3	37	do	1,364
Do	Twenty-eight, No. 2	38	do	1,428
Do	Twenty-eight, No. 7	39	do	1,421
Do	Twenty-eight, No. 15	40	do	1,456
Do	Twenty-eight, No. 16	41	do	1,505
Do		42	do	
Do		49	do	
Do		44	do	
Do		45	do	
Do		46	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		48	NE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		49	do	
Do		50	do	
Do		51	do	
Do		52	do	
Do	Hanford, No. 1	54	NW. ¼ sec. 28, T. 19 S., R. 15 E.	1,356
Do	Hanford, No. 2	55	do	1,379
Do	Hanford, No. 3	56	do	1,404
Do	Hanford, No. 4	57	do	1,385
Do	Hanford, No. 5	58	SW. ¼ sec. 28, T. 19 S., R. 15 E.	1,376
Do	Hanford, No. 6	59	NW. ¼ sec. 28, T. 19 S., R. 15 E.	1,387
Do	Hanford, No. 7	60	do	1,469
Do	Hanford, No. 8	61	SW. ¼ sec. 28, T. 19 S., R. 15 E.	1,341
Do		62	NE. ¼	

a Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Standard		63	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		64	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		65	....do	
Do		66	....do	
Do		67	NE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		68	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		69	NE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a] 70	....do	
Do		[a] 71	....do	
Do		[a] 72	....do	
Do		[a] 73	....do	
Do		[a] 74	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a] 75	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a] 76	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a] 77	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a] 78	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
Standard	Fauna, No. 1	(b)	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Stanislaus		[b] 1	NW. ¼ sec. 4, T. 22 S., R. 17 E.	
Star		[b] 1	NW. ¼ sec. 34, T. 19 S., R. 15 E.	
Stockholders		1	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,486
Do		2	....do	1,385
Do		3	....do	1,394
Do		4	....do	1,407
Do		5	....do	1,454
Stockton		[b] 2	NW. ¼ sec. 30, T. 22 S., R. 18 E.	
Sunnyside	Henshaw	[c] 1	SE. ¼ sec. 35, T. 20 S., R. 14 E.	
S. W. and B		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,061
Do		2	....do	1,038
Do		3	....do	1,031
Do		4	....do	982
Do		[c] 5	....do	
Tavern		[b] 1	Sec. 34, T. 18 S., R. 15 E.	
T. C		1	SW. ¼ sec. 2, T. 19 S., R. 15 E.	958
Traders	Marengo, No. 1	1	SW. ¼ sec. 24, T. 20 S., R. 14 E.	[d] 790
Do	Marengo, No. 2	2	....do	[d] 800
Do	Marengo, No. 3	3	....do	[d] 795
Do	Marengo, No. 4	4	....do	[d] 795
Do	Norse, No. 4	5	....do	
Do	Norse, No. 3	6	....do	
Do	Norse, No. 2	7	....do	
Do	Norse, No. 1	8	....do	
Do	Norse, No. 5	9	....do	
Do	Norse, No. 6	[a] 10	....do	
Do	Norse, No. 7	[a] 11	....do	
Do	Traders, Old, No. 4	12	....do	833
Do	Traders, Old, No. 5	13	....do	[d] 843
Do	Euclid, No. 2	22	....do	824
Do		23	....do	
Do	Euclid, No. 1	24	....do	814
Do	Marengo, No. 7	25	....do	
Do	Marengo, No. 6	26	....do	
Do	Marengo, No. 5	27	....do	
Do	Traders, Old, No. 3	32	....do	845
Do	Traders, Old, No. 2	33	....do	818
Do	Traders, Old, No. 1	34	....do	810
Do	Angelus, No. 1	39	NE. ¼ sec. 28, T. 20 S., R. 14 E.	
Do	Angelus, No. 2	40	....do	
Do	Angelus, No. 4	43	....do	
Twenty-eight. (See Standard.)				
Twenty-two		1	SE. ¼ sec. 22, T. 19 S., R. 15 E.	1,143
Do		[a] 2	....do	
Turner		[a] 1	SW. ¼ sec. 2, T. 20 S., R. 15 E.	[d] 1,075
Do		[a] 2	....do	[d] 975
Union		1	NW. ¼ sec. 13, T. 20 S., R. 14 E.	812
Do		2	NE. ¼ sec. 13, T. 20 S., R. 14 E.	811
Do		3	....do	810
Do		4	NW. ¼ sec. 13, T. 20 S., R. 14 E.	817
Do		5	....do	808
Do		6	....do	824
Do		7	....do	817
Do		8	....do	837
Do		9	....do	835
Do		10	....do	
Do		11	NE. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		12	....do	
Do		13	....do	

[a] Drilling. [b] Abandoned. [c] Water well. [d] Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Union		14	NE. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		15	....do	
Do		16	....do	
Do		17	....do	
Do		18	....do	
Do		19	....do	
Valley		1	SW. ¼ sec. 32, T. 20 S., R. 15 E.	
Venus		[a]1	NW. ¼ sec. 5, T. 22 S., R. 14 E.	
Wabash		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	806
Do		2	....do	802
Do		3	....do	798
Do		4	....do	793
Do		5	....do	789
Do		6	....do	787
Do		7	....do	782
Do		8	....do	796
Do		9	....do	783
Do		10	....do	779
Do		11	....do	777
Do		12	....do	775
Do		13	....do	
Do		14	....do	
Do		15	....do	
Do		16	....do	
Do		17	....do	
Waratah			SW. ¼ sec. 6, T. 21 S., R. 15 E.	
Ward		1	NW. ¼ sec. 12, T. 20 S., R. 14 E.	933
Do		2	....do	934
Do		3	....do	
Do		4	....do	
Do		5	....do	
Do		6	....do	
West Coalinga (water)		1	NE. ¼ sec. 12, T. 21 S., R. 14 E.	1,052
Westlake-Rommel		[a]3	NE. ¼ sec. 2, T. 21 S., R. 14 E.	
Westmoreland. (See California Oilfields, Ltd.)				
Whale	King	[a]1	Sec. 4, T. 22 S., R. 14 E.	
Whittier and Green		[a]1	NW. ¼ sec. 26, T. 20 S., R. 14 E.	
Wisconsin		[a]1	NE. ¼ sec. 32, T. 19 S., R. 15 E.	
W. K		1	NW. ¼ sec. 2, T. 20 S., R. 15 E.	920
Do		2	....do	1,125
Do		[b]3	NE. ¼ sec. 2, T. 20 S., R. 15 E.	[c]960
W. M. & M. (formerly California Diamond, No. 3).	Ellis, No. 1	1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,192
Do	California Diamond, No. 4.	2	....do	1,196
Wright Association		[a]1	NW. ¼ sec. 26, T. 20 S., R. 14 E.	
Yellowstone	Coalinga Southern	[b]1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	917
York Coalinga		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,123
Do		2	....do	1,085
Zenith. (See Section One.)				
Zier		1	SW. ¼ sec. 1, T. 20 S., R. 14 E.	939
Do		2	....do	938
Do		3	....do	964
Do		4	....do	970
Do		5	....do	945
Do		6	....do	939
Do		7	....do	953
Do		8	....do	
Do		9	SE. ¼ sec. 1, T. 20 S., R. 14 E.	
Do		10	....do	
Do		11	....do	
Do		12	....do	

[a] Abandoned. [b] Drilling. [c] Approximate.

The following table, showing the number of wells owned by the several companies in each land section in the Coalinga district October 31, 1909, excluding permanently abandoned wells, was compiled from reliable sources in the field by R. W. Dallas and Guy H. Salisbury.

Oil companies and number of wells in Coalinga district October 31, 1909.

Company.	Location.	Drilling wells.	Drilling wells suspended.	Producing wells suspended.	Producing wells.	Number of derricks, old and new.	Date.[a]
OIL CITY FIELD.							
Coast Range Oil Co	Sec. 17, T. 19 S., R. 15 E				2		1897
Coalinga Oil Co	Sec. 20, T. 19 S., R. 15 E				8		1897
Home Oil Co	do				8		1897
EASTSIDE FIELD.							
North Extension Oil Co	Sec. 20, T. 18 S., R. 15 E					1	1908
Big Shell Petroleum Oil Co	Sec. 29, T. 18 S., R. 15 E		1				1906
North Limited Oil Co	Sec. 34, T. 18 S., R. 15 E					1	1908
Imperial Oil Co. (Coalinga)	Sec. 2, T. 19 S., R. 15 E		4				1908
Wm. Graham (T. C. Oil Co.)	do	1	1	1	1		1907
Chas. Wilcox	do					2	1907
Kern Trading and Oil Co	Sec. 3, T. 19 S., R. 15 E	2					1909
California Oilfields, Ltd	Sec. 10, T. 19 S., R. 15 E				3		1908
Kern Trading and Oil Co	Sec. 11, T. 19 S., R. 15 E	2				1	1908
Lorene Oil Co	Sec. 12, T. 19 S., R. 15 E		1				1908
British Cons. Oil Corp., Ltd	do	1					1907
California Oilfields, Ltd	Sec. 14, T. 19 S., R. 15 E	1	1		5		1904
California Oilfields, Ltd	Sec. 21, T. 19 S., R. 15 E	1	1		9		1904
Camwell Oil Syndicate	Sec. 22, T. 19 S., R. 15 E	2			2		1906
Coalinga Peerless Oil Co	do	3		1	13	1	1905
Associated (National 30) Co	do	1			5		1907
Sauer Dough Oil Co	do				10		1900
Caribou Oil Mining Co	do	1			19		1900
Twenty-two Oil Co	do	1	1				1907
Octave Oil Co. (Merced lease)	do	1					1908
Record Oil Co	do	2		1	4		1907
Good Luck Oil Co	do	1					1909
Scott-Clark-Miller et al	Sec. 24, T. 19 S., R. 15 E					1	
Boston and California Oil Co	do		1				1907
Montana Oil Co	do		1				1907
Pittsburg Oil Co	do		1				1906
British Cons. Oil Corp., Ltd	Sec. 26, T. 19 S., R. 15 E	1		1			1906
Porter Oil Co	do					1	1909
California Oilfields, Ltd	do	3	1		1		1906
Do	Sec. 27, T. 19 S., R. 15 E	4	3		82	2	1903
Standard Oil Co	Sec. 28, T. 19 S., R. 15 E	9		10	53	1	1903
Stockholders' Oil Co	do				5		1899
California Oilfields, Ltd	Sec. 34, T. 19 S., R. 15 E	3			12	1	1906
Kern Trading and Oil Co	Sec. 35, T. 19 S., R. 15 E	3			1	1	1908
Medara Oil Co	Sec. 36, T. 19 S., R. 15 E						1909
Turner Oil Co	Sec. 2, T. 20 S., R. 15 E		2				1907
W. K. Oil Co	do	4					1907
Coalinga Mohawk Oil Co	Sec. 12, T. 20 S., R. 15 E			1		2	1907
Electra Oil Co	Sec. 6, T. 20 S., R. 15 E					1	1909
Southeastern Limited Oil Co	Sec. 18, T. 20 S., R. 16 E	1					1909
Light Oil Extension Oil Co	Sec. 6, T. 20 S., R. 16 E					1	1909
WESTSIDE FIELD.							
California Oilfields, Ltd	Sec. 29, T. 19 S., R. 15 E				2		1903
Ætna Petroleum Oil Co	Sec. 30, T. 19 S., R. 15 E		1				1901
Kern Trading and Oil Co	Sec. 31, T. 19 S., R. 15 E				5		1902
Confidence Oil Co	do			1	10		1901
Maine State Oil Co	do		2				1901
Guthrey Oil Co	do		1	1	2		1907
Commercial Petroleum Co	do	2		2	7		1901
Woy, Mechan, and Madsen	do		1	1			1905
Empire Oil Co	Sec. 32, T. 19 S., R. 15 E	1					1909
Call Oil Co	do	1			2		1906

[a] Date original company began work drilling for oil. The absence of date indicates that no actual work other than assessment work has been done.

Oil companies and number of wells in Coalinga district October 31, 1909—Continued.

Company.	Location.	Drilling wells.	Drilling wells suspended.	Producing wells suspended.	Producing wells.	Number of derricks, old and new.	Date.
WESTSIDE FIELD—continued.							
American Petroleum Co	Sec. 32, T. 19 S., R. 15 E.						1908
Fresno-San Francisco Oil Co	Sec. 1, T. 20 S., R. 14 E.			3	4		1903
Penn-Coalinga Petroleum Co	do			1	4	1	1902
Cypress Oil Co	do				4		1903
Zier Oil Co	do				12	1	1902
Acorn Oil Co	Sec. 2, T. 20 S., R. 14 E.	1					1909
Gold Tip Oil Co	do	1					
Shawmut Oil Co	Sec. 12, T. 20 S., R. 14 E.	1		1	4		1906
Ward Oil Co	do				6		1907
Seneca Oil Co	do				5		1908
St. Clair Oil Co	do			1	2		1908
Pilot Oil Co	do				5		1908
New Era Oil Co	do			1	1		1908
Buntin & Brix Oil Co	do	1		2	3		1906
British Cons. Oil Corp., Ltd. (P. M. D. & O.).	do	1			5		1904
Union Oil Co	Sec. 13, T. 20 S., R. 14 E.	3			15	1	1903
Kern Trading and Oil Co	do	5			9	2	1908
Coalinga Petroleum Co	Sec. 14, T. 20 S., R. 14 E.			3	4	1	1905
Queen Oil Co	do				2		1908
St. Elmo Oil Co. (Home Oil Co.)	do				5		1907
Arizona Petroleum Co	do	1			3		1909
Coalinga Western Oil Co	Sec. 23, T. 20 S., R. 14 E.			5			1906
St. Paul-Fresno Oil Co	do				7		1901
Kern Trading and Oil Co	do				3		1908
Inca Oil Co	Sec. 24, T. 20 S., R. 14 E.	1		2	21	2	1903
Traders' Oil Co	do			2	13	2	1907
Wabash Oil Co	do	1		2	13		1902
Claremont Oil Co	do	1			9	1	1907
Premier Oil Co	do	2			8	1	1907
Kern Trading and Oil Co	Sec. 25, T. 20 S., R. 14 E.	6	1	3	13	1	1904
Ozark Oil Co	Sec. 26, T. 20 S., R. 14 E.			1	3		1907
Traders Oil Co	do				4		1907
Wrenn & McQuigg	do		1				1909
Caledonian Oil Co	do			3	1		1902
Coalinga Homestake Oil Co	do				3		1908
Netherlands Oil Co	do	2					1909
San Juan Oil Co	do						1909
Circle Oil Co	Sec. 35, T. 20 S., R. 14 E.				1		1908
Associated Oil Co	Sec. 36, T. 20 S., R. 14 E.	9	2	2	21	1	1907
Claremont Oil Co	Sec. 4, T. 20 S., R. 15 E.	1				2	1907
Mercantile Crude Oil Co	Sec. 6, T. 20 S., R. 15 E.			2	3		1902
York Coalinga Oil Co	do	1		2	3	1	1902
S. W. and B. Oil Co	do		1		4		1906
New San Francisco Crude Oil Co	do	1			6		1906
Esperanza Oil and Gas Co	do			2	9	1	1900
Section Seven Oil Co	Sec. 7, T. 20 S., R. 15 E.			2	3		1903
Coalinga Pacific Oil Co	do			1	4		1904
Arica Oil Co. (Porter & Scribner)	do	1		3	1	1	1903
M., K. and T. Oil Co	Sec. 8, T. 20 S., R. 15 E.	1		1			1901
California-Coalinga Oil Co	do	1					1909
Coalinga-National Petroleum Co	do	1					1909
Peerless Consolidated Oil Co	Sec. 10, T. 20 S., R. 15 E.		1				1907
American Petroleum Co	Sec. 18, T. 20 S., R. 15 E.	2		1	6		1908
Nevada Petroleum Co	do	1					1909
Kern Trading and Oil Co	Sec. 19, T. 20 S., R. 15 E.	3				1	
American Petroleum Co	Sec. 19, T. 20 S., R. 15 E.	4			4		1909
Nevada Petroleum Co	Sec. 20, T. 20 S., R. 15 E.	1					
American Petroleum Co	Sec. 30, T. 20 S., R. 15 E.	6			7	5	1908
Nevada Petroleum Co	Sec. 30, T. 20 S., R. 15 E.	3			1		1909
Kern Trading and Oil Co	Sec. 31, T. 20 S., R. 15 E.	1					
Valley Oil Co	Sec. 32, T. 20 S., R. 15 E.	1					1909
Elaine Oil Co	Sec. 12, T. 21 S., R. 14 E.					1	1909
Fifty-seven Oil Co	Sec. 12, T. 21 S., R. 15 E.	1					
Coalinga Great Western Co	do	1					1909
Coalinga Unity Co	do					1	1909
Coalinga Twelve Co.	do					1	1909
California Oil and Gas Co	Sec. 6, T. 21 S., R. 15 E.	1	1	1	1		1907
Lucile Oil Co	do	1		1	2		1906
Shreeves Oil Co	do	1					1907
Muriel Oil Co	do	1					1907
Jefferson Oil Co	do	1			1	1	1908

Oil companies and number of wells in Coalinga district October 31, 1909—Continued.

Company.	Location.	Drilling wells.	Drilling wells suspended.	Producing wells suspended.	Producing wells.	Number of derricks, old and new.	Date.
WESTSIDE FIELD—continued.							
Sauer Dough Oil Co	Sec. 6, T. 21 S., R. 15 E		1				1908
Amy Oil Co	do			1			1909
De Luxe Oil Co	do	1					1909
Coalinga Aladdin Oil Co	do			1			1909
Coalinga Red Top Oil Co	do	1					1909
Silver Tip Oil Co	do				1		1909
Blue Moon Oil Co	do	1					1909
Los Angeles Coalinga Oil Syndicate	do	1					1909
Marion Oil Co	do				1		1909
KREYENHAGEN FIELD.							
Boychester Oil Co	Sec. 18, T. 21 S., R. 15 E					1	1909
Coalinga Hub Oil Co	Sec. 22, T. 21 S., R. 15 E	1					1909
Coalinga Alpha Oil Co	do	1					1909
Azores Oil Co	Sec. 26, T. 21 S., R. 15 E	1				1	1909
Glaydas Oil Co	do						1909
People's Associated Oil Co	Sec. 32, T. 21 S., R. 15 E	1					1908
Express Oil Co	Sec. 24, T. 21 S., R. 15 E	1				1	
Golden Crest Oil Co	Sec. 12, T. 22 S., R. 15 E	1					1907
Robertson Oil Co	Sec. 6, T. 22 S., R. 16 E					1	1909
British Cons. Oil Corp., Ltd	do						1909
Southern Coalinga Oilfields	do						1909
Moslem Oil Co	Sec. 20, T. 22 S., R. 16 E					1	1909
Black Mountain Oil Co	Sec. 33, T. 22 S., R. 16 E			2			1900
Smith & Byrner	do	1					1909
Lake View Oil Co	Sec. 26, T. 21 S., R. 17 E		1				1908
Esperanza Land and Oil Co	Sec. 30, T. 21 S., R. 15 E	1					1905
Jacalitos Oil Co	do		1				1907
Mount Hamilton Land and Oil Co	Sec. 14, T. 21 S., R. 14 E		1				1903
Blair Oil Co	Sec. 14, T. 21 S., R. 15 E	1					1908
Cornelius Oil Co	Sec. 4, T. 23 S., R. 16 E						
El Cerrito Oil Co	Sec. 14, T. 23 S., R. 17 E	1					1907
Art Anderson et al	Sec. 22, T. 23 S., R. 17 E					1	1909
Uno Oil Co	Sec. 26, T. 23 S., R. 17 E						
Normandie Oil Co	Sec. 30, T. 23 S., R. 18 E	1					1909
Etsenhausen Oil Co	Sec. 27, T. 24 S., R. 18 E					1	
Best Yet Oil Co						1	
Baird Oil Co		1					1909
Bohemian Oil Co		1					1909
Echo Oil Co						1	
Portola Oil Co		1					1909
Coalinga South Pole Oil Co						1	
NORTHWEST FIELD.							
Michigan Oil and Development Co	Sec. 8, T. 19 S., R. 13 E		1				1907
Wartham Oil Co	Sec. 33, T. 20 S., R. 13 E		1				1908
SUMMARY OF FIELDS.							
Oil City field					18		
Eastside field		48	19	15	228	17	
Westside field		80	13	55	304	29	
Kreyenhagen field		15	3	2		10	
Northwest field			2				
		143	37	72	550	56	

CHEMICAL AND PHYSICAL EXAMINATION OF THE PETROLEUMS OF THE COALINGA DISTRICT.

By IRVING C. ALLEN.

METHODS OF EXAMINATION.

Specific gravity.—The specific gravity was determined by means of a Westphal balance when the quantity of the oil was more than 9 cubic centimeters, and by means of a Nicoll picnometer when the quantity was less. The Westphal balance is well known, and no description is necessary.

As the Nicoll picnometer is of special though simple construction, it is probably less well known, and a brief description is here given. Its accuracy with the lighter oils is unquestioned; with the more viscous oils some difficulty is encountered in drying the end tubes before the final weighings, but with care accurate results to the fourth decimal place can be attained. Its value lies in the ease with which it can be made and in the facility with which it can be used to determine the specific gravity of small quantities of liquids, even as little as 0.2 to 0.3 gram.

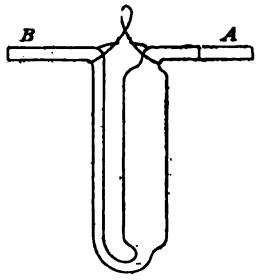


FIGURE 9.—Small picnometer.

It is made as follows: A quarter to sixteenth inch tube of soft glass, depending on the size of the picnometer desired, is drawn out in two places with an interval of about one inch into two tubes of capillary diameter. It will almost always occur that one of these capillary tubes will be of slightly greater diameter than the other, and this capillary (A) is bent through an angle of 90°. The other or smaller capillary (B) is bent through 180° back along the body of the tube to a point opposite the first, then again through 90° away from the first, as shown in figure 9. The ends of A and B are cut off at about equal distances from the body of the tube and carefully smoothed off in a flame. A mark is etched on the larger tube (A) about midway between the bend and the end. The whole is fitted with a fine platinum wire so that it can be suspended from the balance arm. A rubber cap is made for tube A.

Now the tube with cap is weighed empty (W_1). The cap is removed and the tube is then drawn full of distilled water at a temperature of 15° C., and the water, with the aid of a bit of filter paper applied to B, is drawn accurately to the mark on A. The cap is replaced and the tube and contents weighed (W_2). $W_2 - W_1$ gives the water content of the picnometer at 15° C.

The same procedure with an oil gives W_2, and $W_2 - W_1$ gives the oil content at 15° C; and $\frac{W_2 - W_1}{W_3 - W_1}$ gives the specific gravity of the oil at 15° C.

Because the Baumé scale for indicating gravity, in the writer's opinion a deplorable system, is in common use, and for the convenience of those unfamiliar with the specific gravity, the corresponding Baumé degree is set opposite each specific-gravity degree.

Flash point.—The flash point was determined in an Abel or a Pensky closed tester, the instrument being carefully screened to avoid air currents.

Calorific value.—The calorific value was determined in a Berthelot combustion bomb (Dinsmore-Atwater model)—that is, by burning a small quantity of the oil in pure oxygen under a pressure of 30 atmospheres. This method is rapid and accurate and is in general use.

Sulphur.—The sulphur was determined by carefully washing out the contents of the bomb, after the combustion, with distilled water, precipitating the sulphuric acid therein with barium chloride in the usual way, and calculating the percentage of sulphur.

Fractional distillation.—For the proximate analysis or fractional distillation the form and size of retort recommended by Engler (Redwood on Petroleum) was adopted, with the change, however, that the side tube turns upward instead of downward at an angle of 75° with the neck for a length of 4 centimeters, and is then bent downward to the original angle of 75°. This, with care in adjusting the flame, prevents the bumping over of the retort contents and insures a cleaner distillate. First the oil is distilled under normal pressure to 200° to 250° C. (Cracking begins at about 330° C.) The receiver is then replaced with a fresh one and the distillation continued under a vacuum approaching 40 centimeters of mercury pressure, the best attainable with the water vacuum pump at hand, to a temperature of 330° to 350° C.—that is, until practically all liquid is over and only a hard brittle mass of asphaltum remains when cooled. From 330° up cracking sometimes occurs, though not always, the oils differing markedly in this respect from the Pennsylvania oils, and as a result practically all available "oils" are separated from the asphaltum and sediment.

These distillations are united and carefully fractioned in the ordinary Engler retort, taking fractions every 25° C. according to the procedure of Engler. The specific gravity of these fractions is also determined. The distillations are done by weight, retorts and all receivers being weighed empty and with contents, thus reducing the loss to a minimum—that is, from 1 per cent to 4 and 5 per cent with the more volatile oils.

This interrupted or intermittent Engler method of distillation leaves much to be desired. Mixtures of bodies so closely resembling one another in all their properties as those constituting crude petroleum are very difficult of separation, and the values given in the accompanying tables can not be considered as absolute, but will give a very fair idea of the technological constituents of these petroleums, and will aid in the more elaborate separations to be carried on later.

The method of continuous or uninterrupted distillation now considered to yield the most uniform results will be adopted in the bulletins to follow.

RESULTS OF EXAMINATION.

The table that follows shows in detail the results of the examination of these oils. In the columns under the headings "Naphtha," "Burning oil," "Lubricating oil," "Asphaltum," and "Paraffin wax," the results of the fractional distillation are summarized in order to give an idea of the bodies of economic importance to be found in the distillates.

The sulphur and water content of these oils is low, comparing most favorably with that of other California oils, and the calorific value is uniform and good.

Results of chemical and physical examination of the petroleums of the Coalinga district.

Laboratory No.	Lease.	Well No.	Location.	Geologic zone.	Date of sampling (1907).	Specific gravity at 15° C.	Baumé at 60° F.	Flash point.
							°B.	°F.
1	California Oil-fields, Ltd.	1	Sec. 14, T. 19 S., R. 15 E.	Top of D	Oct. 31	0.9326	20.2	92
2	Peerless	7	Sec. 22, T. 19 S., R. 15 E.	do	do	0.9335	20.0	72
3	Do	11	do	Bottom of D	do	0.9493	17.6	128
4	Sauer Dough (A.O.)	5	do	D	do	0.9220	22.0	63
5	A. O. National 30	1	do	D	do	0.9291	20.8	87
7	Carabou	1	do	Top of D	do	0.9215	22.1	60
8	Record	1	do	Bottom of D	Oct. 30	0.9393	19.2	121
10	Standard	27 28	Sec. 28, T. 19 S., R. 15 E.	C and D	do	0.9243	21.6	75
12	California Oil-fields, Ltd.	13	Sec. 27, T. 19 S., R. 15 E.	C	do	0.8718	30.7	Below 53
14	Do	31	do	D	Oct. 31	0.9097	24.2	Below 53
16	California Monarch	1	Sec. 26, T. 19 S., R. 15 E.	Top of D	do	0.9324	20.3	111
17	California Oil-fields, Ltd.	8	Sec. 34, T. 19 S., R. 15 E.	B	do	0.9299	20.7	66
19	W. K	1	Sec. 2, T. 20 S., R. 15 E.	Top of D	do	0.9305	20.6	87
21	Coast Range (Old Home).	3	Sec. 17, T. 19 S., R. 15 E.	Chico	Oct. 10	0.8533	34.2	Below 53
23	Coalinga	7	Sec. 20, T. 19 S., R. 15 E.	do	do	0.8519	34.5	Below 53
24	Home	5	do	do	do	0.8570	33.5	Below 53
25	Hanford	7	Sec. 28, T. 19 S., R. 15 E.	C and D	do	0.9439	18.4	115
28	Standard	11	do	do	do	0.9416	18.8	Below 65
31	Commercial Petroleum.	1	Sec. 31, T. 19 S., R. 15 E.	B	do	0.9341	20.0	92
32	Do	9	do	B	do	0.9401	19.0	96
33	Maine State or Guthrey 3.	3	do	Top of B	do	0.9568	16.4	+167
35	California Monarch (Maine State).	8	do	B and top of D	do	0.9451	18.2	150
36	Confidence	11	do	B	do	0.9615	15.7	Above 167
39	Kern Trading	3	do	B	do	0.9457	18.2	131
40	Mercantile Crude	1	Sec. 6, T. 20 S., R. 15 E.	Top of B	do	0.9559	16.5	Above 167
41	Do	4	do	Second sand in B.	do	0.9706	14.3	Above 167
42	York Coalinga	2	do	B	do	0.9672	14.8	Above 167
43	New San Francisco Crude.	5	do	B	do	0.9738	13.8	Above 167
45	Esperanza	6	do	Top of B	do	0.9472	17.9	130
47	Zier	4	Sec. 1, T. 20 S., R. 14 E.	B	Oct. 9	0.9760	13.5	Above 167
48	Do	5	do	B	do	0.9662	15.0	Above 167
50	R. H. Herron	1	do	B	do	0.9771	13.3	Above 167
53	Pennsylvania Coalinga.	3	do	Top of B	Oct. 10	0.9503	17.4	153
55	Shawmut	2	Sec. 12, T. 20 S., R. 14 E.	Bottom of B	Oct. 9	0.9499	17.5	155
56	Section Seven	4	Sec. 7, T. 20 S., R. 15 E.	B	Oct. 10	0.9501	17.5	146
58	Coalinga Pacific	1	do	Top of B	Oct. 9	0.9526	17.1	145
60	Union	2	Sec. 13, T. 20 S., R. 14 E.	B	do	0.9750	13.6	Above 167
61	Do	4	do	Top of B	do	0.9655	15.0	Above 167
62	Do	9	do	Probably B	do	0.9715	14.1	Above 167
64	Coalinga Petroleum	4	Sec. 14, T. 20 S., R. 14 E.	B	do	0.9810	12.7	Above 167
65	New Home	1	do	B	do	0.9783	13.1	Above 167
66	Do	2	do	B	do	0.9777	13.2	.....
68	Coalinga Western	3	Sec. 23, T. 20 S., R. 14 E.	B	do	0.9820	12.6	Above 167
72	St. Paul Fresno	4	do	B	do	0.9833	12.4	Above 167

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Location.	Geologic zone.	Date of sampling (1907).	Specific gravity at 15° C.	Baumé at 60° F.	Flash point.
							°B.	°F.
73	Inca	5	Sec. 24, T. 20 S., R. 14 E.	B	Oct. 9	0.9581	16.2	+167
75	Do	7	do	B	do	0.9601	15.9	Above 167
77	Wabash	8	do	B	do	0.9583	16.2	Above 167
78	Do	10	do	B	do	0.9585	16.2	Above 167
79	Do	6	do	B	do	0.9581	16.2	+167
80	Cal. and N. Y. or P. M. & D. Co.	1	Sec. 12, T. 20 S., R. 14 E.	B and possibly top of D.	do	0.9517	17.2	148
81	Do	4	do	B	do	0.9670	14.8	Above 167
82	Fresno and San Francisco.	4	Sec. 1, T. 20 S., R. 14 E.	B	Oct. 10	0.9729	14.0	Above 167
83	Lucile	1	Sec. 6, T. 21 S., R. 15 E.	Lower part of upper section of D.	do	0.9533	17.0	131

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Calorific value.	Sulphur.	Water.	Fractional distillation (not refined).							
						75°–100°.		100°–125°.		125°–150°.		150°–175°.	
						Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.
1	California Oilfields Ltd	1	10,601	P. ct. 0.40	P. ct. 0.05	.....	.....	.....	.....	0.7454	0.33	0.7800	0.95
2	Peerless	7	10,584	0.40	0.00	.....	.....	.....	.....	.....	.....	0.7994	5.65
3	Do	11	10,592	0.60	0.05	.....	.....	.....	.....	.....	.....	0.7824	0.36
4	Sauer Dough(A.O.)	5	10,608	0.37	0.00	0.8652	0.25	07347	0.88	0.7755	2.60	0.7943	3.67
5	A. O. National 30	1	10,656	0.39	0.12	.....	.....	.....	0.36	0.7615	1.23	0.7908	2.52
7	Carabou	1	10,632	0.39	0.00	.....	.....	0.7406	0.39	0.7590	1.39	0.7933	5.15
8	Record	1	10,596	0.53	0.12	.....	.....	.....	.....	.....	0.23	0.8252	0.76
10	Standard	{27 28}	10,599	0.37	0.00	.....	0.30	0.7268	0.75	0.7682	1.80	0.7903	5.27
12	California Oilfields, Ltd	13	10,685	0.35	0.00	0.6860	2.97	0.7173	4.22	0.7526	6.16	0.7814	5.56
14	Do	31	10,619	0.35	0.00	.....	.....	0.7231	0.40	0.7467	1.66	0.7846	4.57
16	California Monarch	1	10,576	0.38	0.00	.....	.....	.....	0.47	0.7513	0.87	0.7861	2.14
17	California Oilfields, Ltd	8	10,581	0.44	0.12	0.7412	0.73	0.7518	0.65	0.7702	0.73	0.7869	2.54
19	W. K	1	10,605	0.40	0.00	.....	.....	0.7604	0.51	0.7764	0.25	0.7963	3.08
21	Coast Range (Old Home)	3	10,657	.....	0.00	0.7719	0.67	0.7742	10.64	0.8075	18.53	0.8290	15.85
23	Coalinga	7	10,748	0.03	0.00	0.7522	1.83	0.7768	5.35	0.8100	18.01	0.8309	15.51
24	Home	5	10,683	0.05	0.00	0.7308	0.63	0.7688	3.97	0.8032	21.72	0.8294	16.92
25	Hanford	7	10,577	0.51	0.00	.....	.....	0.7536	0.45	0.7769	0.67	0.7960	0.97
28	Standard	11	10,515	0.50	0.00	.....	.....	0.7143	0.58	0.7566	0.90	0.7785	1.68
31	Commercial Petroleum	1	10,563	0.47	0.00	.....	.....	.....	0.16	0.7726	0.48	0.7991	1.23
32	Do	9	10,633	0.50	0.00	.....	.....	0.7424	0.78	0.7753	0.73	0.7929	0.95
33	Maine State or Guthrey 3	3	10,502	0.48	0.10	0.7441	0.36	.....	0.14	0.7632	0.29	0.8025	0.72
35	California Monarch (Maine State)	8	10,514	0.48	0.60	.....	.....	.....	.....	.....	.....	0.7924	0.74
36	Confidence	11	10,493	0.55	0.00	.....	.....	.....	.....	.....	.....	.....	.....
39	Kern Trading	3	10,517	0.60	0.00	0.7165	0.95	0.7510	1.74	0.7823	2.45	0.7981	2.84
40	Mercantile Crude	1	10,495	0.63	0.00	.....	.....	.....	.....	.....	.....	0.8016	0.59
41	Do	4	10,432	0.71	0.00	0.7176	0.38	0.7463	0.38	.....	0.33	0.7889	0.22
42	York Coalinga	2	10,456	0.70	.....	.....	.....	.....	.....	.....	.....	.....	0.32
43	New San Francisco Crude	5	10,305	0.70	0.87	.....	.....	.....	.....	.....	.....	.....	.....
45	Esperanza	6	10,523	0.51	0.00	.....	0.11	0.7790	0.47	0.8022	0.29	0.8150	1.06
47	Zier	4	10,242	0.72	0.00	.....	.....	.....	.....	.....	.....	0.8294	0.46
48	Do	5	10,448	0.64	Trace.	.....	.....	.....	.....	.....	.....	.....	.....
50	R. H. Herron	1	10,365	0.73	0.00	.....	.....	.....	.....	.....	.....	.....	.....
53	Pennsylvania Coalinga	3	10,545	0.51	0.00	.....	.....	.....	.....	.....	.....	0.8023	1.39
55	Shawmut	2	10,539	0.54	0.00	.....	.....	.....	.....	0.7979	0.27	0.7980	0.60
56	Section Seven	4	10,508	0.54	Trace.	.....	.....	.....	.....	0.7870	0.65	0.8158	0.86
58	Coalinga Pacific	1	10,478	0.57	0.00	.....	.....	.....	.....	.....	.....	.....	.....
60	Union	2	10,422	0.72	0.00	.....	.....	.....	.....	.....	.....	.....	.....
61	Do	4	10,408	0.72	0.00	.....	.....	.....	.....	.....	.....	0.8268	0.54
62	Do	9	10,446	0.71	Trace.	.....	.....	.....	.....	.....	.....	.....	.....
64	Coalinga Petroleum	4	10,402	0.69	0.11	0.7060	0.32	0.7369	0.37	0.7641	0.48	0.7853	0.37
65	New Home	1	10,369	0.70	0.82	.....	.....	.....	.....	.....	.....	.....	.....
66	Do	2	10,361	0.71	0.75	.....	.....	.....	.....	.....	.....	0.7879	0.28
68	Coalinga Western	3	9,887	0.70	5.36	.....	.....	.....	.....	.....	.....	.....	.....
72	St. Paul Fresno	4	10,356	0.76	0.30	.....	.....	.....	.....	.....	.....	.....	.....
73	Inca	5	10,491	0.60	0.00	.....	.....	.....	.....	.....	.....	0.8087	0.35
75	Do	7	10,505	0.59	0.00	.....	.....	.....	.....	.....	.....	.....	.....
77	Wabash	8	10,497	0.59	0.09	.....	.....	.....	.....	0.7951	0.41	0.8046	0.37
78	Do	10	10,480	0.59	0.06	.....	.....	.....	.....	0.8036	0.12	0.8036	0.34
79	Do	6	10,463	0.60	0.32	.....	.....	.....	.....	.....	.....	.....	.....
80	Cal. and N. Y. or P. M. & D. Co	1	10,548	0.54	0.06	.....	.....	.....	.....	.....	.....	0.7716	0.45
81	Do	4	10,432	0.68	0.12	.....	.....	.....	.....	.....	.....	.....	.....
82	Fresno and San Francisco	4	10,415	0.77	0.05	.....	.....	.....	.....	.....	.....	0.7872	0.17
83	Lucile	1	10,416	0.54	0.74	.....	.....	0.7800	0.40	0.7886	0.45	0.7986	0.59

Results of chemical and physical examination of the petroleums of the Coalinga district Continued.

Laboratory No.	Lease.	Well No.	Fractional distillation (not refined)—Continued.									
			175°–200°.		200°–225°.		225°–250°.		250°–275°.		275°–300°.	
			Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct
1	California Oilfields, Ltd	1	0.8152	3.81	0.8400	4.38	0.8606	5.86	0.8754	6.29	0.8904	8.8
2	Fearless	7	0.8289	1.89	0.8386	5.00	0.8630	5.58	0.8801	7.32	0.8962	10.5
3	Do	11	0.8104	1.75	0.8264	2.07	0.8536	4.85	0.8726	6.87	0.8897	6.3
4	Sauer Dough(A.O.)	5	0.8229	5.03	0.8428	5.45	0.8650	6.87	0.8808	8.58	0.9002	11.25
5	A. O. National 30	1	0.8105	4.62	0.8404	6.05	0.8633	6.77	0.8788	7.06	0.8958	10.52
7	Carabou	1	0.8202	4.57	0.8449	4.76	0.8647	5.28	0.8809	7.60	0.8945	6.35
8	Record	1	.....	.....	1.83		0.8492	4.48	0.8679	6.30	0.8825	6.98
10	Standard	27 28	0.8215	3.99	0.9045	5.27	0.8656	8.13	0.8833	8.96	0.8971	8.50
12	California Oilfields, Ltd	13	0.8063	5.02	0.8249	4.22	0.8444	5.24	0.8626	5.89	0.8791	5.37
14	Do	31	0.8067	3.92	0.8302	3.36	0.8527	5.42	0.8703	6.83	0.8841	8.28
16	California Monarch	1	0.8159	3.96	0.8398	5.30	0.8682	7.74	0.8824	9.64	0.8978	8.69
17	California Oilfields, Ltd	8	0.8079	2.54	0.8365	5.52	0.8585	6.17	0.8756	8.21	0.8918	9.15
19	W. K	1	0.8305	3.97	0.8495	4.54	0.8678	8.96	0.8860	8.58	0.9002	10.23
21	Coast Range (Old Home)	3	0.8469	8.56	0.8704	9.83	0.8983	9.57	0.9145	8.69	0.9223	5.22
23	Coalinga	7	0.8537	9.35	0.8747	7.79	0.8987	9.21	0.9192	9.00	0.9288	4.26
24	Home	5	0.8473	9.33	0.8727	9.89	0.9004	12.05	0.9178	7.45	0.9272	4.66
25	Hanford	7	0.8216	2.60	0.8546	2.38	0.8693	7.07	0.8899	6.32	0.9047	7.89
28	Standard	11	0.8159	2.91	0.8449	2.97	0.8652	5.29	0.8859	7.10	0.9119	7.94
31	Commercial Petroleum	1	0.8233	3.05	0.8509	5.40	0.8682	5.94	0.8867	8.23	0.9026	8.66
32	Do	9	0.8154	2.40	0.8410	4.47	0.8636	6.21	0.8795	7.16	0.8967	9.61
33	Maine State or Guthrey 3	3	0.8130	1.37	0.8418	3.66	0.8646	6.54	0.8822	5.97	0.8985	9.64
35	California Monarch (Maine State)	8	0.8180	1.73	0.8352	2.91	0.8584	3.90	0.8774	6.51	0.8945	7.50
36	Confidence	11	0.8123	0.47	0.8370	1.36	0.8606	3.46	0.8759	4.65	0.8946	7.65
39	Kern Trading	3	0.8266	3.47	0.8462	4.74	0.8648	6.87	0.8851	9.24	0.9018	8.06
40	Mercantile Crude	1	0.8208	1.23	0.8456	2.45	0.8671	4.15	0.8828	6.07	0.8986	6.55
41	Do	4	0.8225	1.14	0.8504	1.31	0.8632	3.43	0.8811	6.26	0.8978	8.71
42	York Coalinga	2	0.8314	0.53	0.8645	2.65	0.8730	3.02	0.8864	5.50	0.9032	6.09
43	New San Francisco Crude	5	0.8646	0.41	0.8602	1.02	0.8731	3.46	0.8882	3.51	0.9039	9.15
45	Esperanza	6	0.8443	1.53	0.8501	3.00	0.8689	6.23	0.8902	7.76	0.9046	7.52
47	Zier	4	0.8388	0.87	0.8612	0.93	0.8749	2.15	0.8865	5.57	0.9030	7.48
48	Do	5	0.8207	0.36	0.8519	1.19	0.8713	4.97	0.8866	5.03	0.9015	6.40
50	R. H. Herron	1	.....	.....	0.8505	0.40	0.8725	1.48	0.8863	4.51	0.8965	5.99
53	Pennsylvania Coalinga	3	0.8297	1.51	0.8503	3.25	0.8696	6.21	0.8868	5.80	0.9037	8.07
55	Shawmut	2	0.8253	2.33	0.8488	3.35	0.8635	3.95	0.8844	7.41	0.9042	8.70
56	Section Seven	4	0.8365	2.16	0.8553	3.07	0.8754	6.68	0.8919	6.52	0.9064	7.60
58	Coalinga Pacific	1	0.8181	1.72	0.8438	3.11	0.8669	5.32	0.8853	5.89	0.9014	8.39
60	Union	2	0.8093	0.47	0.8522	0.99	0.8688	2.10	0.8853	5.49	0.9027	6.89
61	Do	4	0.8292	1.12	0.8504	1.21	0.8389	3.88	0.8857	5.88	0.9031	6.69
62	Do	9	0.8352	0.50	0.8544	0.90	0.8675	3.19	0.8852	4.98	0.9029	7.95
64	Coalinga Petroleum	4	0.8326	0.96	0.8611	1.23	0.8755	2.56	0.8884	4.59	0.9042	7.68
65	New Home	1	.....	Trace.	0.8166	0.36	0.8598	0.72	0.8793	4.31	0.8985	6.21
66	Do	2	0.8064	0.42	0.8412	0.51	0.8674	2.25	0.8865	3.55	0.9089	6.32
68	Coalinga Western	3	.....	.....	0.8553	0.54	0.8786	2.03	0.8877	3.62	0.9007	5.74
72	St. Paul Fresno	4	.....	.....	0.8445	0.74	0.8752	1.08	0.8865	4.52	0.9014	4.37
73	Inca	5	0.8218	1.05	0.8491	2.10	0.8685	4.90	0.8884	7.23	0.9052	7.12
75	Do	7	0.8234	1.32	0.8478	1.45	0.8662	4.15	0.8822	5.77	0.9007	6.81
77	Wabash	8	0.8271	0.42	0.8444	2.02	0.8634	5.06	0.8828	5.85	0.8992	7.96
78	Do	10	0.8335	0.46	0.8475	1.94	0.8635	2.79	0.8821	5.54	0.8984	8.16
79	Do	6	0.8235	0.53	0.8481	2.33	0.8634	3.75	0.8902	5.07	0.8973	6.97
80	Cal. and N. Y. or P. M. & D. Co	1	0.8076	1.23	0.8404	2.63	0.8590	4.15	0.8811	7.40	0.8964	7.12
81	Do	4	.....	.....	0.8522	0.90	0.8614	2.08	0.8797	5.78	0.8981	7.46
82	Fresno and San Francisco	4	0.8277	0.30	0.8496	0.50	0.8691	2.03	0.8811	5.58	0.8968	6.38
83	Lucile	1	0.8191	0.89	0.8443	2.33	0.8683	4.71	0.8817	4.76	0.8967	6.35

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Fractional distillation (not refined)—Continued.							
			300°–325°.		325°–350°.		350°–375°.		375°–400°.	
			Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.
1	California Oilfields, Ltd.	1	0.9050	8.05	0.9147	7.53	0.9217	19.82	0.9382	3.76
2	Peerless	7	0.9097	8.69	0.9212	36.06				
3	Do	11	0.9040	8.22	0.9180	9.20	0.9282	11.93	0.9387	9.61
4	Saner Dough (A.O.)	5	0.9123	8.23	0.9214	8.00	0.9303	17.35		
5	A. O. National 30	1	0.9104	9.22	0.9180	18.66	0.9375	15.78		
7	Carabou	1	0.9062	6.39	0.9183	7.98	0.9138	15.38	0.9332	3.80
8	Record	1	0.9118	8.65	0.9154	10.71	0.9090	11.09	0.9563	4.94
10	Standard	{27 28}	0.9120	8.43	0.9176	19.80	0.9331	9.90		
12	California Oilfields, Ltd.	13	0.8926	4.97	0.9063	7.67	0.9141	11.84		
14	Do	31	0.8947	7.03	0.9083	9.84	0.9145	11.90	0.9230	6.32
16	California Monarch	1	0.9103	8.28	0.9157	15.41	0.9283	18.50		
17	California Oilfields, Ltd.	8	0.9084	9.08	0.9078	14.89	0.9160	15.32	0.9632	5.38
19	W. K.	1	0.9112	8.38	0.9184	17.53	0.9421	11.32		
21	Coast Range (Old Home)	3	0.9823	2.34	0.9522	1.84		(a)		(a)
23	Coalinga	7	0.9384	2.30				(a)		(a)
24	Home	5	0.9334	3.20	0.9419	1.19		(a)		(a)
25	Hanford	7	0.9186	10.12	0.9303	9.08	0.9386	17.18		
28	Standard	11	0.9164	7.56	0.9298	9.69	0.9371	8.97	0.9513	4.97
31	Commercial Petroleum	1	0.9186	10.91	0.9226	13.96	0.9308	5.46		
32	Do	9	0.9100	7.49	0.9084	30.18	0.9469	7.60		
33	Maine State or Guthrey 3	3	0.9148	9.42	0.9234	20.78	0.9442	16.03		
35	California Monarch (Maine State)	8	0.9092	7.65	0.9233	8.59	0.9313	9.08	0.9442	7.21
36	Confidence	11	0.9117	7.35	0.9250	7.79	0.9363	15.26	0.9483	8.59
39	Kern Trading	3	0.9175	10.27	0.9265	20.78	0.9557	7.50		
40	Mercantile Crude	1	0.9126	7.98	0.9270	6.97	0.9358	8.41	0.9492	4.25
41	Do	4	0.9133	11.00	0.9172	26.89	0.9469	4.35		
42	York Coalinga	2	0.9160	7.57	0.9330	8.84	0.9433	7.04		
43	New San Francisco Crude	5	0.9200	11.29	0.9300	20.65	0.9700	5.64		
45	Esperanza	6	0.9204	9.23	0.9302	11.52	0.9381	12.57	0.9680	2.94
47	Zier	4	0.9184	8.93	0.9335	11.14	0.9439	14.67		
48	Do	5	0.9170	7.78	0.9336	9.75	0.9386	11.00	0.9580	4.66
50	R. H. Herron	1	0.9108	7.37	0.9254	10.34	0.9323	7.66	0.9454	5.83
53	Pennsylvania Coalinga	3	0.9206	7.08	0.9330	10.10	0.9360	11.32		
55	Shawmut	2	0.9202	7.79	0.9333	9.57	0.9366	11.35	0.9543	4.06
56	Section Seven	4	0.9229	8.35	0.9350	5.93	0.9424	12.34		
58	Coalinga Pacific	1	0.9182	8.92	0.9280	10.21	0.9367	12.70	0.9593	4.36
60	Union	2	0.9188	7.88	0.9348	10.28	0.9469	10.21		
61	Do	4	0.9190	7.84	0.9294	11.49	0.9441	14.66		
62	Do	9	0.9191	6.88	0.9329	7.62	0.9447	6.38	0.9628	2.80
64	Coalinga Petroleum	4	0.9201	9.07	0.9335	12.06	0.9486	14.41	0.9662	1.28
65	New Home	1	0.9112	6.47	0.9261	7.59	0.9367	9.85	0.9509	5.75
66	Do	2	0.9129	10.48	0.9285	9.31	0.9365	19.60	0.9644	1.26
68	Coalinga Western	3	0.9147	5.61	0.9289	8.14	0.9405	7.46	0.9523	4.97
72	St. Paul Fresno	4	0.9162	7.08	0.9291	8.90	0.9381	9.39	0.9680	4.18
73	Inca	5	0.9219	9.74	0.9362	7.53	0.9449	7.06	0.9567	2.80
75	Do	7	0.9168	8.83	0.9285	11.60	0.9390	13.39	0.9649	1.09
77	Wabash	8	0.9149	9.71	0.9251	12.10	0.9384	21.08		
78	Do	10	0.9159	9.13	0.9299	7.42	0.9394	10.79	0.9524	4.16
79	Do	6	0.9121	7.45	0.9264	9.67	0.9356	12.68	0.9543	6.50
80	Cal. and N. Y. or P. M. & D. Co.	1	0.9128	8.02	0.9268	8.91	0.9352	12.95	0.9436	11.88
81	Do	4	0.9129	6.83	0.9261	7.86	0.9395	9.42	0.9461	8.33
82	Fresno and San Francisco	4	0.9115	6.72	0.9254	8.62	0.9331	14.58	0.9558	6.17
83	Lucile	1	0.9068	6.45	0.9229	7.78	0.9349	9.82	0.9452	6.19

[a] See column headed "Paraffin wax."

Results of chemical and physical examination of the petroleums of the Coalinga dist
Continued.

Laboratory No.	Lease.	Well No.	Naphthas (below 150° C.).	Burning oil a (150°–300° C.).	Lubricating oils a (300°–400° C.).	Asphaltum (above 400° C.).	Paraffin wax.	Residue.	L
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per*
1	California Oilfields, Ltd	1	0.33	30.10	39.16	25.30	.....	3.57	
2	Peerless	7	0.00	35.71	44.75	8.83	.....	5.94	
3	Do	11	0.00	22.20	38.96	31.97	.....	5.58	
4	Sauer Dough (A. O.)	5	3.73	40.85	33.58	16.22	.....	2.54	
5	A. O. National 30	1	1.59	37.54	43.66	8.07	.....	4.47	
7	Carabou	1	1.78	33.71	33.55	24.62	.....	5.33	
8	Record	1	0.23	30.15	35.39	28.24	.....	3.86	
10	Standard	{27 {28	2.85	40.12	38.13	10.09	.....	5.27	
12	California Oilfields, Ltd	13	13.35	31.30	24.48	20.31	.....	6.89	3
14	Do	31	2.06	32.38	34.59	25.10	.....	4.27	1
16	California Monarch	1	1.34	37.47	42.29	12.65	.....	3.32	2
17	California Oilfields, Ltd	8	2.11	34.13	44.67	12.92	.....	2.25	3
19	W. K	1	0.76	39.36	37.23	17.02	.....	1.92	3
21	Coast Range (Old Home)	3	29.84	57.72	3.68	2.68	3.54	1.20	1
23	Coalinga	7	25.19	55.12	2.30	8.12	4.47	1.62	3
24	Home	5	26.32	60.30	4.39	1.89	4.18	1.60	1
25	Hanford	7	1.12	27.23	36.38	30.65	.....	1.79	2
28	Standard	11	1.48	27.89	31.19	36.15	.....	1.42	1
31	Commercial Petroleum	1	0.64	32.51	30.33	28.45	.....	6.04	2
32	Do	9	1.51	30.80	45.27	14.87	.....	4.03	3
33	Maine State or Guthrey 3	3	0.79	27.90	46.23	17.83	.....	3.59	3.
35	California Monarch (Maine State)	8	0.00	23.29	32.53	41.07	.....	1.53	0.
36	Confidence	11	0.00	17.59	38.99	40.68	.....	1.84	0.
39	Kern Trading	3	5.14	35.22	38.55	14.30	.....	3.00	3.
40	Mercantile Crude	1	0.00	21.04	27.61	48.75	.....	1.86	0.
41	Do	4	1.09	21.07	42.24	27.33	.....	4.90	3.
42	York Coalinga	2	0.00	18.11	23.45	55.95	.....	1.75	0.
43	New San Francisco Crude	5	0.00	17.55	37.58	38.71	.....	3.05	2.24
45	Esperanza	6	0.87	27.10	36.26	32.19	.....	2.23	1.35
47	Zier	4	0.00	17.46	34.74	43.16	.....	2.55	2.09
48	Do	5	0.00	17.95	33.19	45.16	.....	1.97	1.73
50	R. H. Herron	1	0.00	12.38	31.20	49.46	.....	5.48	1.48
53	Pennsylvania Coalinga	3	0.00	26.23	28.50	39.35	.....	4.82	1.10
55	Shawmut	2	0.27	26.34	32.77	37.43	.....	2.38	0.81
56	Section Seven	4	0.65	26.89	26.62	42.35	.....	2.26	1.23
58	Coalinga Pacific	1	0.00	24.43	36.19	36.13	.....	1.72	1.53
60	Union	2	0.00	15.94	28.37	53.77	.....	0.40	1.52
61	Do	4	0.00	19.32	33.99	42.36	.....	2.50	1.83
62	Do	9	0.00	17.52	23.68	56.78	.....	1.12	0.90
64	Coalinga Petroleum	4	1.17	17.39	36.82	40.13	.....	1.87	2.51
65	New Home	1	0.00	11.60	29.66	54.64	.....	2.31	0.97
66	Do	2	0.00	13.33	40.65	41.53	.....	1.82	1.92
68	Coalinga Western	3	0.00	11.93	26.18	54.54	.....	1.27	0.72
72	St. Paul Fresno	4	0.00	10.71	29.55	57.42	.....	0.59	1.43
73	Inca	5	0.00	22.75	27.13	48.43	.....	1.05	0.64
75	Do	7	0.00	19.50	34.91	40.34	.....	3.46	1.79
77	Wabash	8	0.41	21.68	42.89	30.33	.....	2.53	2.07
78	Do	10	0.12	19.23	31.50	45.78	.....	2.34	0.97
79	Do	6	0.00	18.65	36.30	41.99	.....	1.69	1.05
80	California and N. Y. or P. M. & D. Co	1	0.00	22.98	41.76	31.62	.....	2.30	1.28
81	Do	4	0.00	16.22	32.44	49.31	.....	1.50	0.41
82	Fresno and San Francisco	4	0.00	14.96	36.09	44.84	.....	2.79	1.27
83	Lucile	1	0.85	19.63	30.24	46.75	.....	1.09	0.70

a These values represent the unrefined fractions.

PLATE XXIII.

PLATE XXIII.

CHICO (UPPER CRETACEOUS) FOSSILS.

VOLUTODERMA GABBI White.

Page.

Figure 1. Natural size. Catalogue No. 20112, U.S.N.M.; copied from Bull. U. S. Geol. Survey No. 51, pl. 3, fig. 1. Found at locality 3 in the Coalinga district; also occurs as far north as Puget Sound region..... 60

PERISSOLAX BREVIROSTRIS Gabb.

Figure 2. Natural size. Copied from Whiteaves, Geol. Survey Canada, Mes. Foss., vol. 1, pt. 5, pl. 43, fig. 3, 1903. Found at locality 4 in the Coalinga district; a not uncommon species in the Chico of the Pacific coast..... 60

TELLINA? OOIDES Gabb.

Figure 3. Exterior of imperfect left valve, showing a little of the original shell material, altitude 43 mm., natural size. Catalogue No. 31075, U.S.N.M. Found at locality 3 in the Coalinga district, and at other Chico localities on the west coast..... 60

MACTRA ASHBURNERI Gabb.

Figure 4. Exterior of small right valve, longitude 28 mm., × 2. Catalogue No. 31074, U.S.N.M. Found at locality 3 in the Coalinga district; also common at most Chico localities..... 60

MEEKIA SELLA Gabb.

Figure 5. Exterior of cast of right valve, altitude 18 mm., × 2. Catalogue No. 31073, U.S.N.M. Locality 3 in Coalinga district; also common at other Chico localities on the Pacific coast..... 60

AVICULA LINGUÆFORMIS Evans and Shumard.

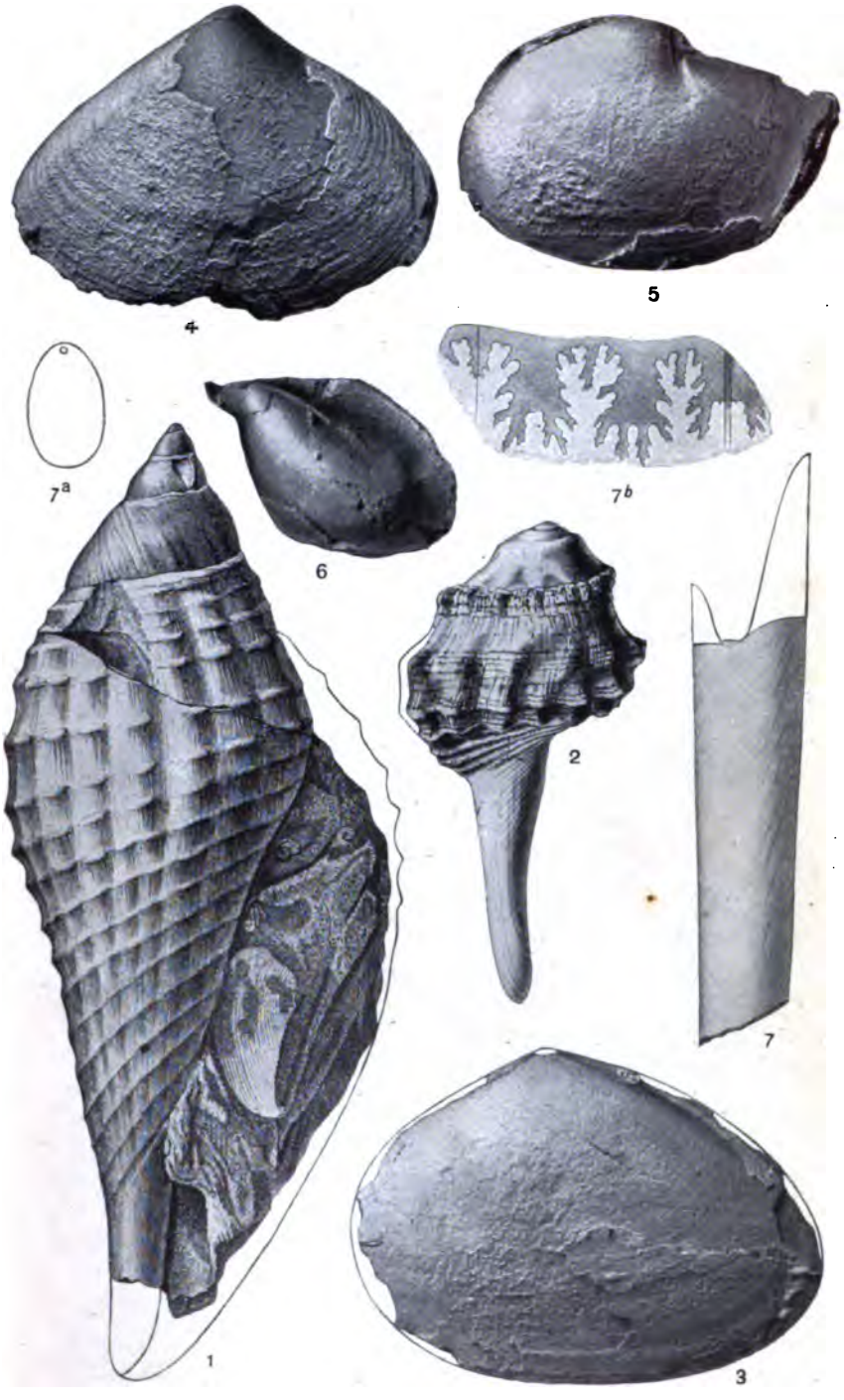
Figure 6. Exterior of cast of small left valve, altitude 14 mm., × 2. Catalogue No. 31076, U.S.N.M. Locality 11..... 60

BACULITES CHICOENSIS Trask.

Figure 7. Natural size. Copied from Gabb, Pal. California, vol. 1, pl. 17, figs. 27, 27a, 1864.

7a. Cross section. Idem, figure 27a.

7b. Septum. Idem, plate 14, figure 28b.



CHICO FOSSILS.

PLATE XXIV.

PLATE XXIV.

TEJON (EOCENE) PELECYPODA.

VENERICARDIA PLANICOSTA Lamarck.

Page.

Figure 1. Left valve; longitude 84 mm. Eocene; Little Falls, Wash. Catalogue No. 164973, U.S.N.M. This is the most widespread and characteristic Eocene species in the world.

CORBULA PARILIS Gabb.

Figure 2. Exterior of right valve restored, longitude 6 mm., × 2. Catalogue No. 165621, U.S.N.M. Locality 4801..... 70

SEPTIFER DICHOTOMUS Gabb.

Figure 3. Exterior of right valve restored, longitude 22 mm., × 2. Catalogue No. 165623, U.S.N.M. Locality 4801..... 70

OSTREA IDRIAENSIS Gabb.

Figure 4. Exterior of right valve, longitude 27 mm., natural size. Catalogue No. 165674, U.S.N.M. Locality 4801..... 70

Figure 5. Exterior of left valve, longitude 35.5 mm., natural size. Catalogue No. 165674, U.S.N.M. Locality 4801. A common species in certain California Eocene localities..... 70

SPONDYLUS CARLOSENSIS F. M. Anderson.

Figure 6. Exterior of imperfect specimen, altitude 20 mm., natural size. Catalogue No. 165628, U.S.N.M. Locality 4617. So far unknown outside the Coalinga district..... 70

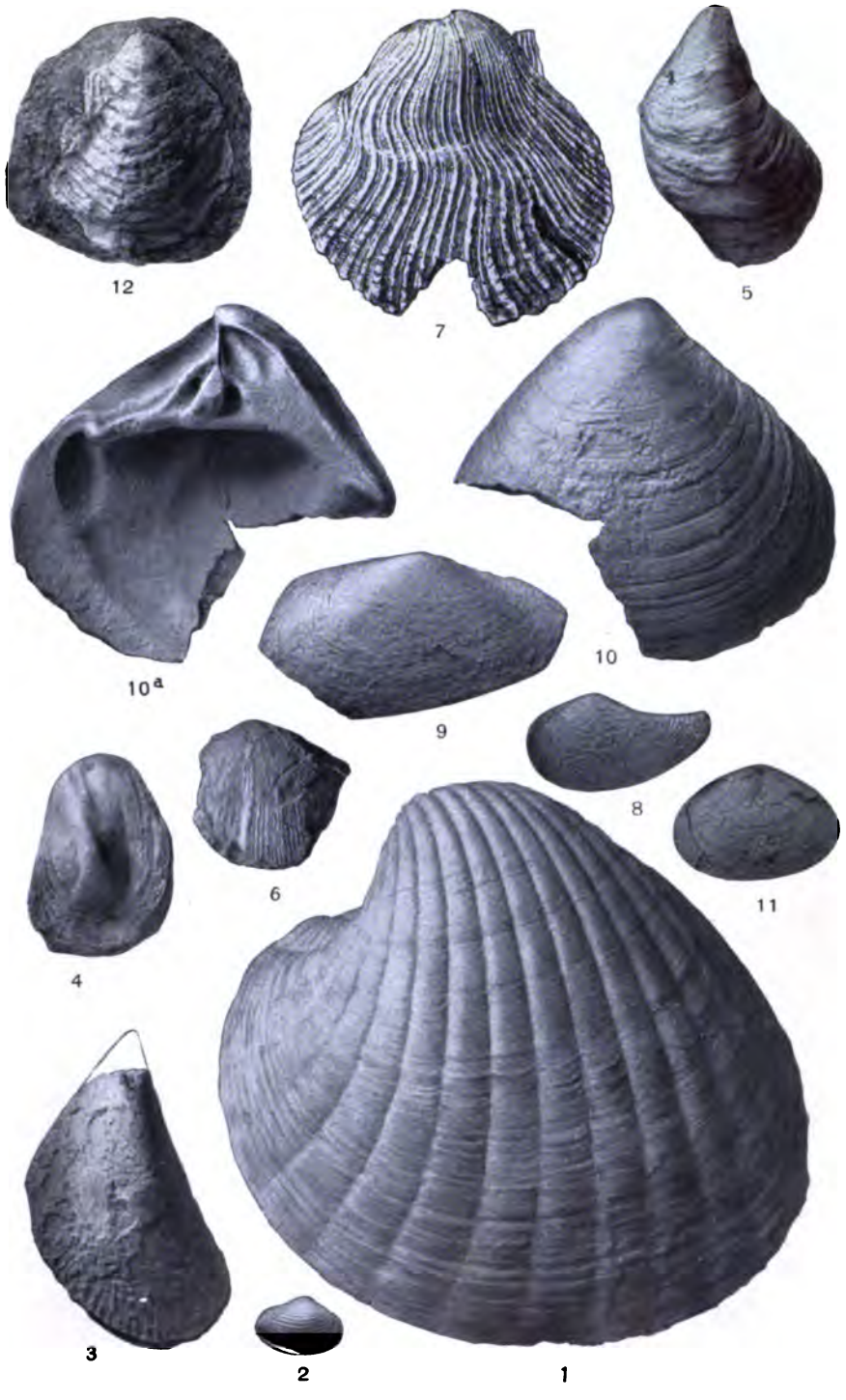
Figure 7. Type of species, natural size. Copied from Proc. California Acad. Sci., 3d ser., Geology, vol. 2, no. 2, pl. 13, fig. 1.

LEDA GABBI Conrad.

Figure 8. Exterior of cast of left valve, longitude 13 mm., × 2. Catalogue No. 165662, U.S.N.M. Locality 5014. A common species in the Tejon..... 70

TELLINA HORNII Gabb.

Figure 9. Exterior of left valve of slightly imperfect specimen, longitude 42 mm., natural size. Catalogue No. 165656, U.S.N.M. Locality 4617. A species found at many Tejon localities..... 70



TEJON PELECYPODA.

CRASSATELLITES GRANDIS Gabb.

Page.

Figure 10. Exterior of imperfect right valve, altitude 50 mm., natural size. Catalogue No. 165638, U.S.N.M. Locality 4613. A common Tejon species 70

10a. Interior of same specimen.

TELLINA JOAQUINENSIS Arnold.

Figure 11. Exterior of left valve, longitude 22 mm., natural size. Type, catalogue No. 165619, U.S.N.M. Locality 4801..... 70

OSTREA AVICULIFORMIS F. M. Anderson.

Figure 12. Exterior of left valve, longitude, 16 mm., × 2. Catalogue No. 165627, U.S.N.M. Locality 4801..... 70

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Naphtha[a] (below 150° C.).	Burning oil[a] (150°–300° C.).	Lubricating oil[a] (300°–400° C.).	Asphaltum (above 400° C.).	Paraffin wax.	Residue.	Loss.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	California Oilfields, Ltd.	1	0.33	30.10	39.16	25.30	.....	3.57	1.49
2	Peerless	7	0.00	35.71	44.75	8.83	.....	5.94	4.77
3	Do	11	0.00	22.20	38.96	31.97	.....	5.58	1.24
4	Sauer Dough (A. O.)	5	3.73	40.85	33.58	16.22	.....	2.54	3.06
5	A. O. National 30	1	1.59	37.54	43.66	8.07	.....	4.47	4.55
7	Carabou	1	1.78	33.71	33.55	24.62	.....	5.33	1.01
8	Record	1	0.23	30.15	35.39	28.24	.....	3.86	2.01
10	Standard	27 28	2.85	40.12	38.13	10.09	.....	5.27	3.54
12	California Oilfields, Ltd.	13	13.35	31.30	24.48	20.31	.....	6.89	3.67
14	Do	31	2.06	32.38	34.59	25.10	.....	4.27	1.60
16	California Monarch	1	1.34	37.47	42.29	12.65	.....	3.32	2.93
17	California Oilfields, Ltd.	8	2.11	34.13	44.67	12.92	.....	2.25	3.92
19	W. K.	1	0.76	39.36	37.23	17.02	.....	1.92	3.71
21	Coast Range (Old Home)	3	29.84	57.72	3.68	2.68	3.54	1.20	1.34
23	Coalinga	7	25.19	55.12	2.30	8.12	4.47	1.62	3.18
24	Home	5	26.32	60.30	4.39	1.89	4.18	1.60	1.32
25	Hanford	7	1.12	27.23	36.38	30.65	.....	1.79	2.83
28	Standard	11	1.48	27.89	31.19	36.15	.....	1.42	1.87
31	Commercial Petroleum	1	0.64	32.51	30.33	28.45	.....	6.04	2.03
32	Do	9	1.51	30.80	45.27	14.87	.....	4.03	3.52
33	Maine State or Guthrey 3	3	0.79	27.90	46.23	17.83	.....	3.59	3.66
35	California Monarch (Maine State)	8	0.00	23.29	32.53	41.07	.....	1.53	0.98
36	Confidence	11	0.00	17.59	38.99	40.68	.....	1.84	0.81
39	Kern Trading	3	5.14	35.22	38.55	14.30	.....	3.00	3.79
40	Mercantile Crude	1	0.00	21.04	27.61	48.75	.....	1.86	0.74
41	Do	4	1.09	21.07	42.24	27.33	.....	4.90	3.37
42	York Coalinga	2	0.00	18.11	23.45	55.95	.....	1.75	0.74
43	New San Francisco Crude	5	0.00	17.55	37.58	38.71	.....	3.05	2.24
45	Esperanza	6	0.87	27.10	36.26	32.19	.....	2.23	1.35
47	Zier	4	0.00	17.46	34.74	43.16	.....	2.55	2.09
48	Do	5	0.00	17.95	33.19	45.16	.....	1.97	1.73
50	R. H. Herron	1	0.00	12.38	31.20	49.46	.....	5.48	1.48
53	Pennsylvania Coalinga	3	0.00	26.23	28.50	39.35	.....	4.82	1.10
55	Shawmut	2	0.27	26.34	32.77	37.43	.....	2.38	0.81
56	Section Seven	4	0.65	26.89	26.62	42.35	.....	2.26	1.23
58	Coalinga Pacific	1	0.00	24.43	36.19	36.13	.....	1.72	1.53
60	Union	2	0.00	15.94	28.37	53.77	.....	0.40	1.52
61	Do	4	0.00	19.32	33.99	42.36	.....	2.50	1.83
62	Do	9	0.00	17.52	23.68	56.78	.....	1.12	0.90
64	Coalinga Petroleum	4	1.17	17.39	36.82	40.13	.....	1.87	2.51
65	New Home	1	0.00	11.60	29.66	54.64	.....	2.31	0.97
66	Do	2	0.00	13.33	40.65	41.53	.....	1.82	1.92
68	Coalinga Western	3	0.00	11.93	26.18	54.54	.....	1.27	0.72
72	St. Paul Fresno	4	0.00	10.71	29.55	57.42	.....	0.59	1.43
73	Inca	5	0.00	22.75	27.13	48.43	.....	1.05	0.64
75	Do	7	0.00	19.50	34.91	40.34	.....	3.46	1.79
77	Wabash	8	0.41	21.68	42.89	30.33	.....	2.53	2.07
78	Do	10	0.12	19.23	31.50	45.78	.....	2.34	0.97
79	Do	6	0.00	18.65	36.30	41.99	.....	1.69	1.05
80	California and N. Y. or P. M. & D. Co	1	0.00	22.98	41.76	31.62	.....	2.30	1.28
81	Do	4	0.00	16.22	32.44	49.31	.....	1.50	0.41
82	Fresno and San Francisco	4	0.00	14.96	36.09	44.84	.....	2.79	1.27
83	Lucile	1	0.85	19.63	30.24	46.75	.....	1.09	0.70

[a] These values represent the unrefined fractions.

PLATE XXIII.

PLATE XXV.

TEJON (EOCENE) PELECYPODA.

PLACUNANOMIA INORNATA Gabb.

Page.

Figure 1. Exterior of upper or convex valve, longitude 20 mm., × 2. Catalogue No. 165632, U.S.N.M. Locality 4801. A common form in the supposed brackish-water facies of the Tejon..... 70

PECTEN PECKHAMI Gabb.

Figure 2. Exterior of gutta-percha cast of right valve, altitude 13 mm., natural size. Catalogue No. 165642, U.S.N.M. Locality 4616. Ranges from the Eocene to the Miocene..... 70

2a. Exterior of left valve. Altitude 13.5 mm., natural size.

CARDIUM COOPERI Gabb.

Figure 3. Exterior of slightly broken right valve, altitude 21.5 mm., × 2. Catalogue No. 165637, U.S.N.M. Locality 4617. A species found most abundantly in the lower Eocene, but sometimes also in the Tejon..... 70

MERETRIX GABBI n. sp.

Figure 4. Exterior of right valve, longitude 29 mm., natural size. Type, Catalogue No. 165640, U.S.N.M. Locality 4801..... 70

MERETRIX OVALIS Gabb.

Figure 5. Exterior of left valve, longitude 13 mm., × 2. Catalogue No. 165629, U.S.N.M. Locality 4801. A rather rare species..... 70

ORBITOLITES sp. *a*.

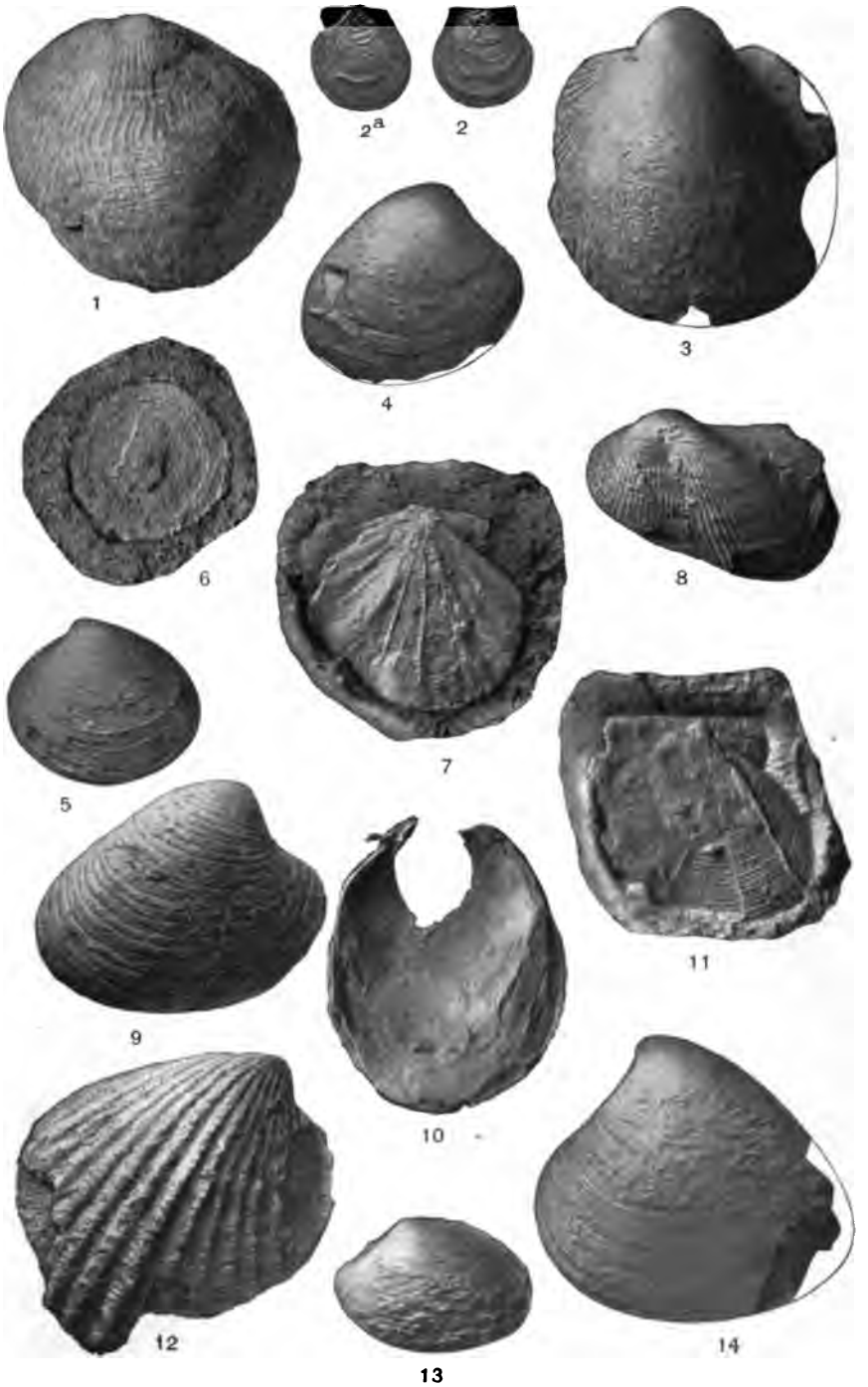
Figure 6. Top, maximum diameter 7.5 mm., × 3. Catalogue No. 165625, U.S.N.M. Locality 4617. A species of foraminifer common in the Tejon..... 70

PECTEN INTERRADIATUS Gabb.

Figure 7. Exterior of cast of right valve, altitude 9 mm., × 3. Catalogue No. 165667, U.S.N.M. Locality 5013. Also known in the shales of the Tejon at New Idria..... 70

BARBATIA MORSEI Gabb.

Figure 8. Exterior of slightly imperfect left valve, longitude 16.5 mm., × 2. Catalogue No. 165635, U.S.N.M. Locality 4801. A common species in the Eocene..... 70



TEJON PELECYPODA.

MERETRIX HORNII Gabb.

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Figure 9. Exterior of right valve, longitude 20 mm., × 2. Catalogue No. 165641, U.S.N.M. Locality 4617. A common Eocene species..... 70

PLACUNANOMIA INORNATA Gabb.

Figure 10. Exterior of lower or flat valve, longitude 20 mm., × 2. Catalogue No. 165633, U.S.N.M. Locality 4609..... 70

PECTEN INTERRADIATUS Gabb.

Figure 11. Exterior of gutta-percha cast, showing external surface somewhat distorted, altitude 7 mm., × 4. Catalogue No. 165634, U.S.N.M. Locality 4616..... 70

VENERICARDIA ALTICOSTA Gabb.

Figure 12. Exterior of slightly imperfect specimen, longitude 41 mm., natural size. Catalogue No. 165626, U.S.N.M. Locality 4621. Much rarer than *V. planicosta* Lamarck..... 70

MERETRIX UVASANA Conrad.

Figure 13. Exterior of lower or flat valve, longitude 20 mm., × 2. Catalogue No. 165633, U.S.N.M. Locality 4619. A common Tejon species. 70

CRASSATELLITES GRANDIS Gabb.

Figure 14. Exterior of left valve, altitude 38 mm., natural size. Catalogue No. 165639, U.S.N.M. Locality 4619..... 70

PLATE XXVI.

PLATE XXVI.

TEJON (EOCENE) GASTEROPODA AND ECHINODERMATA.

CASSIDULUS CALIFORNICUS F. M. Anderson.

Page.

Figure 1. Top view of imperfect specimen, longitude 21 mm., × 2. Catalogue No. 165664, U.S.N.M. Locality 4622. So far known only from this locality..... 70

1a. Bottom of same specimen.

POTAMIDES CARBONICOLA Cooper.

Figure 2. Back of imperfect specimen, longitude 19 mm., × 2. Catalogue No. 165651, U.S.N.M. Locality 4801. So far known only from the type locality..... 71

3. Back of another specimen, longitude 16 mm., × 2. Catalogue No. 165651, U.S.N.M. Same locality as figure 2.

TRITONIUM CALIFORNICUM Gabb.

Figure 4. Front of young and imperfect specimen, longitude 8 mm., × 4. Catalogue No. 165644, U.S.N.M. Locality 4619. A rather rare species; grows to much larger size than the figured specimen..... 71

SERPULORBIS sp. *a*.

Figure 5. Top, maximum diameter of specimen 15 mm., × 2. Catalogue No. 165659, U.S.N.M. Locality 4617. A common form at some localities of the Tejon..... 71

RIMELLA CANALIFERA Gabb.

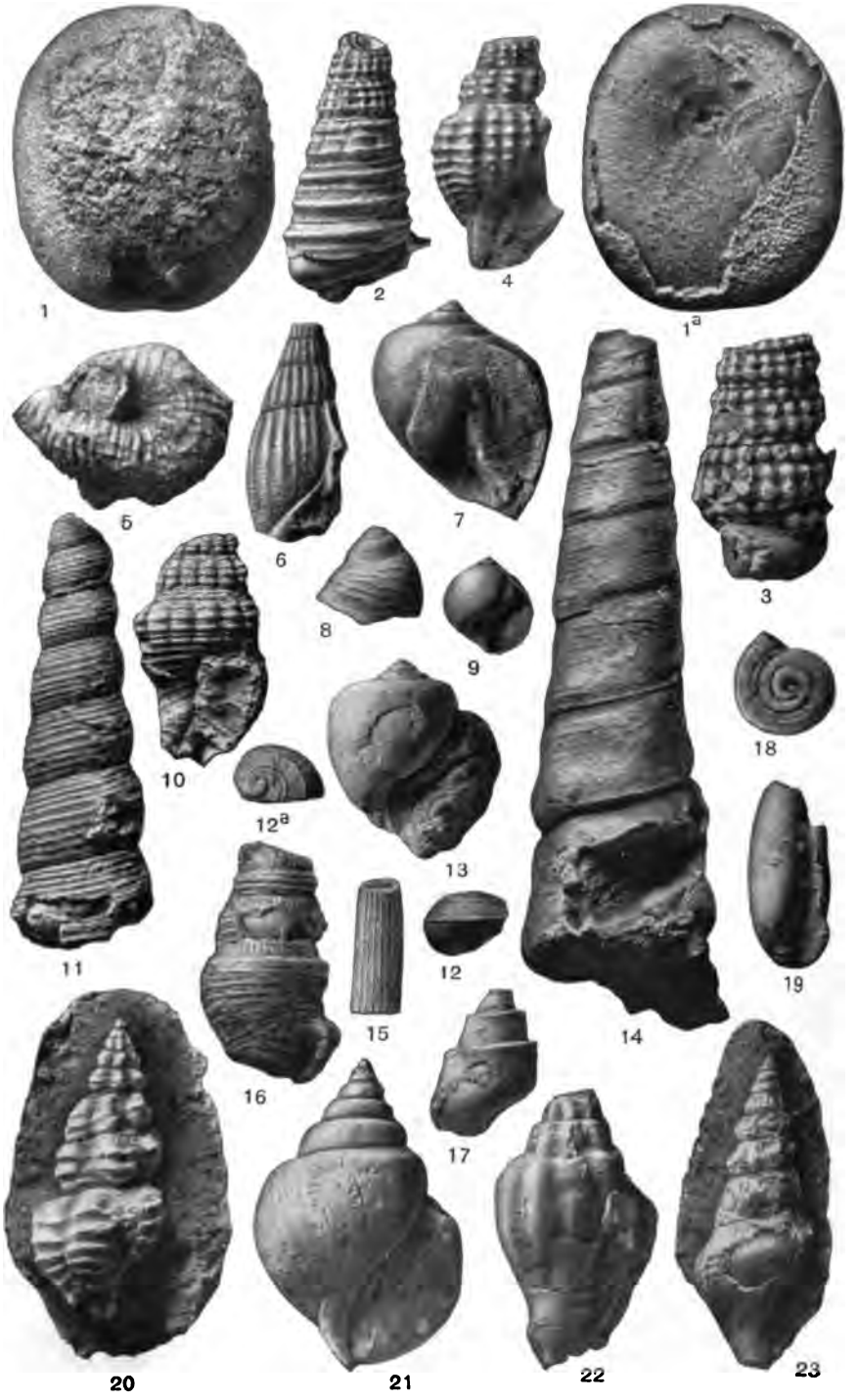
Figure 6. Front of imperfect specimen, longitude 15 mm., × 2. Catalogue No. 165646, U.S.N.M. Locality 4618. This species has an expanded lip which is produced upward along the body and penultimate whorls. A common and characteristic Eocene form.... 71

AMAUROPSIS OVIFORMIS? Gabb.

Figure 7. Front of imperfect specimen, altitude 29 mm., natural size. Catalogue No. 165654, U.S.N.M. Locality 4617..... 71

GALERUS EXCENTRICUS Gabb.

Figure 8. Side view, altitude 12 mm., natural size. Catalogue No. 165643, U.S.N.M. Locality 4801. A very common and characteristic Eocene species..... 71



TEJON GASTEROPODA AND ECHINODERMATA.

LUNATIA HORNII Gabb.

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Figure 9. Front view, altitude 13.3 mm., natural size. Catalogue No. 165620, U.S.N.M. Locality 4801. Often grows much larger than the specimen figured..... 71

TRITONIDEA KREYENHAGENI Arnold.

Figure 10. Front of décolleté and slightly imperfect specimen, longitude 16 mm., × 2. Type, catalogue No. 165657, U.S.N.M. Locality 4801..... 71

TURRITELLA UVASANA Conrad.

Figure 11. Side of a décolleté specimen, longitude 31 mm., × 2. Catalogue No. 165653, U.S.N.M. Locality 4617. A common and characteristic Eocene species, showing considerable variation as regards sculpture..... 71

NERITA TRIANGULATA Gabb.

Figure 12. Back and part of top, maximum diameter 12 mm., natural size. Catalogue No. 165700, U.S.N.M. Locality 4801. A characteristic Eocene species..... 71

12a. Top of same specimen.

LUNATIA sp. *a*.

Figure 13. Front of imperfect specimen, altitude 27 mm., natural size. Catalogue No. 165652, U.S.N.M. Locality 4801..... 71

TURRITELLA PACHECOENSIS Stanton.

Figure 14. Exterior of imperfect young specimen, longitude 44.5 mm., × 2. Catalogue No. 165636, U.S.N.M. Locality 4617. Usually more common in the lower Eocene, but also found in the Tejon..... 71

DENTALIUM COOPERI Gabb.

Figure 15. Side, longitude 9 mm., × 2. Catalogue No. 165622, U.S.N.M. Locality 4619. A common and long-lived species..... 71

PLEUROTOMA DOMENGINEI Arnold.

Figure 16. Side of imperfect specimen, longitude 11 mm., × 3. Type, catalogue No. 165647, U.S.N.M. Locality 4619..... 71

LOXOTREMA TURRITA Gabb.

Figure 17. Back of imperfect specimen, longitude 20 mm., natural size. Catalogue No. 165649, U.S.N.M. Locality 4801. A peculiar and characteristic Tejon species..... 71

SPIROGLYPHUS? TEJONENSIS Arnold.

Figure 18. Top of coil, maximum diameter 7.5 mm., × 2. Type, catalogue No. 165658, U.S.N.M. Locality 4617..... 71

CYLICHNA COSTATA Gabb.

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Figure 19. Front view of imperfect specimen, longitude 13 mm., × 2. Catalogue No. 165655, U.S.N.M. Locality 4617. A common Eocene form very much like some later species of the same genus..... 71

PLEUROTOMA GUIBERSONI Arnold.

Figure 20. Rear view of imperfect specimen, longitude 13.5 mm., × 3. Type, catalogue No. 165648, U.S.N.M. Locality 4619..... 71

AMAUROPSIS ALVEATA Conrad.

Figure 21. Front view of specimen with slightly broken lip, altitude 43 mm., natural size. Catalogue No. 165650, U.S.N.M. Locality 4619. An exceedingly widespread and characteristic species in the Eocene..... 71

CANCELLARIA IRELANIANA Cooper.

Figure 22. Front view of imperfect specimen, longitude 39 mm., natural size. Catalogue No. 165645, U.S.N.M. Locality 4619..... 71

PLEUROTOMA FRESNOENSIS Arnold.

Figure 23. Front view of specimen from which the canal is missing, longitude 21 mm., × 2. Type, catalogue No. 165631, U.S.N.M. Locality 4619..... 71

PLATE XXVII.

PLATE XXVII.

VAQUEROS (LOWER MIOCENE) FOSSILS: LOWER HORIZON.

OSTREA TITAN Conrad.

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Figure 1. Exterior of left valve, longitude 90 mm., natural size. Catalogue No. 165565, U.S.N.M. Lower Vaqueros formation; locality 4773. This rather diminutive variety is found abundantly below the "reef bed" on Laval grade, 9 miles north of Coalinga. 86

DOSINIA MATHEWSONII Gabb.

Figure 2. Exterior of right valve, altitude 56 mm., natural size. Catalogue No. 165596, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the lower and middle Miocene..... 86

MYTILUS MATHEWSONII Gabb var. EXPANSUS Arnold.

Figure 3. Exterior of nearly perfect right valve, longitude 157 mm., natural size. Catalogue No. 165661, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the Vaqueros; the typical form is usually found in the upper half of the Miocene..... 86

SEPTIFER COALINGENSIS Arnold.

Figure 4. Exterior of left valve, longitude 45 mm., natural size. Type, catalogue No. 165580, U.S.N.M. Supposed Vaqueros formation; locality 4634..... 85

TROPHON (FORRERIA) GABBIANUM F. M. Anderson.

Figure 5. Back of imperfect specimen, altitude 44 mm., natural size. Catalogue No. 165572, U.S.N.M. Vaqueros formation; locality 4860. (See Pl. XXVIII, fig. 5)..... 86

MULINIA DENSATA Conrad var. MINOR Arnold.

Figure 6. Exterior of slightly imperfect right valve. Type, catalogue No. 165601, U.S.N.M. Vaqueros formation; locality 4777..... 86

VAQUEROS FOSSILS.

PLATE XXVIII.

PLATE XXVIII.

VAQUEROS (LOWER MIOCENE) FOSSILS: LOWER HORIZON.

METIS aff. ALTA Conrad.

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Figure 1. Exterior of right valve, longitude 32 mm., × 2. Catalogue No. 165567, U.S.N.M. Vaqueros formation; locality 4627. This lower Miocene *Metis* may be different from the Recent *M. alta*, but the state of preservation of the fossils precludes a definite determination 85

2. Left valve of same specimen.

CONUS HAYESI Arnold.

Figure 3. Back of slightly imperfect specimen, longitude 60 mm., natural size. Type, catalogue No. 165566, U.S.N.M. Vaqueros formation; locality 4861 86

SCUTELLA MERRIAMI F. M. Anderson.

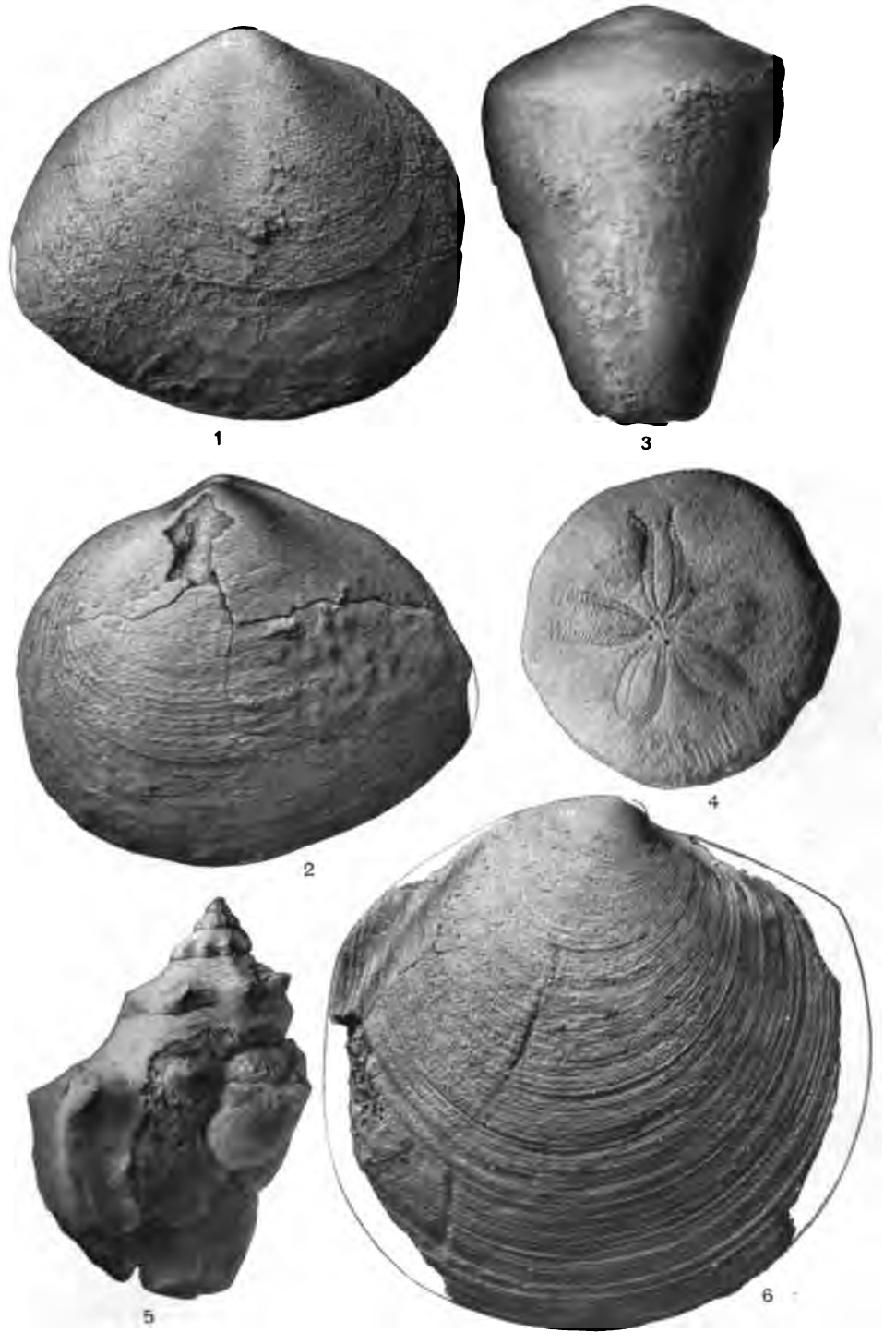
Figure 4. Top, maximum diameter 21 mm., natural size. Catalogue No. 165584, U.S.N.M. Vaqueros formation; locality 4775. This little echinoid from which the "button bed" in the Vaqueros derives its name is found at many localities in the Coalinga district, and is believed to be characteristic of the Vaqueros or lower Miocene 86

TROPHON (FORRERIA) GABBIANUM F. M. Anderson var. CANCELLARIOIDES Arnold.

Figure 5. Back of imperfect specimen, longitude 56 mm., natural size. Type, catalogue No. 165605, U.S.N.M. Vaqueros formation; locality 4861. (See Pl. XXVII, fig. 5) 86

PHACOIDES (MILTHA) SANCTÆCRUCIS Arnold.

Figure 6. Exterior of nearly perfect right valve, longitude 75 mm., natural size. Type, catalogue No. 165569, U.S.N.M. Vaqueros formation; locality 4861 86



VAQUEROS FOSSILS.

PLATE XXIX.

PLATE XXIX.

VAQUEROS (LOWER MIOCENE) FOSSILS: LOWER AND UPPER HORIZONS.

ARCA OSMONTI Dall.

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Figure 1. Exterior of left valve, longitude 49 mm., natural size. Catalogue No. 165563, U.S.N.M. Vaqueros formation; locality 4859. This species is believed to be characteristic of the lower Miocene. The specimen figured is from the type locality. Found also in Santa Monica Mountains, near Los Angeles..... 86

1a. Umbones of same specimen.

2. Exterior of left valve of a broader specimen, longitude 39 mm., natural size. Catalogue No. 165563, U.S.N.M.

TROPHON (FORRERIA) BARTONI Arnold.

Figure 3. Imperfect specimen, altitude 33 mm., natural size. Type, catalogue No. 165571, U.S.N.M. Vaqueros formation; locality 4861..... 86

PECTEN ANDERSONI Arnold.

Figure 4. Exterior of right valve, longitude 37 mm., natural size. Catalogue No. 165583, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the Miocene. It is found abundantly in certain layers of the "reef beds," where it makes up the entire rock for small thicknesses..... 86

ZIRPHÆA DENTATA Gabb.

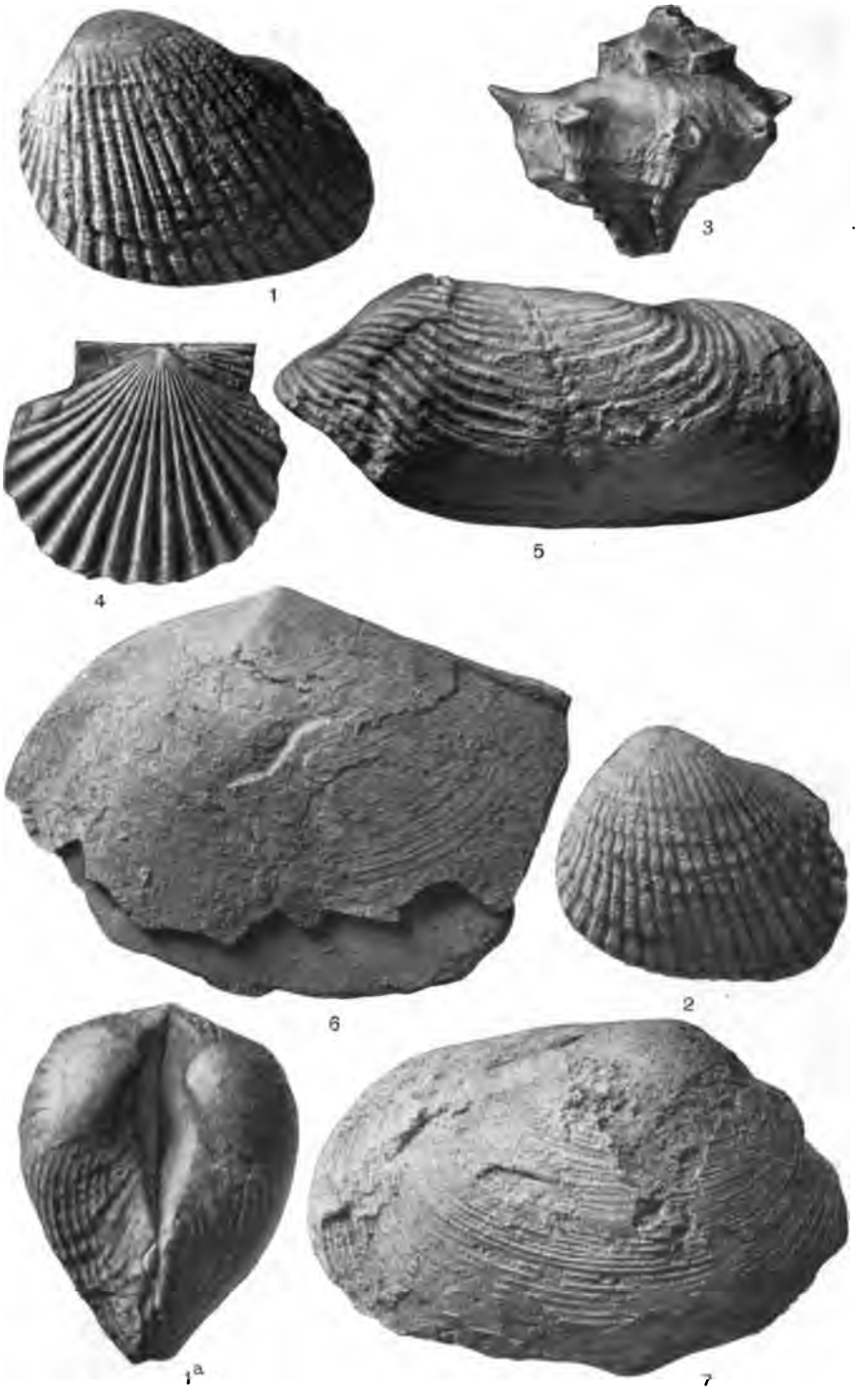
Figure 5. Exterior of left valve, longitude 73 mm., natural size. Catalogue No. 165573, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the Miocene.... 86

MACOMA PIERCEI Arnold.

Figure 6. Exterior of left valve of imperfect specimen, longitude 75 mm., natural size. Type, catalogue No. 165595, U.S.N.M. Upper Vaqueros formation; locality 4631..... 85

SAXIDOMUS VAQUEROSENSIS Arnold.

Figure 7. Exterior of left valve, longitude 69 mm., natural size. Type, catalogue No. 165570, U.S.N.M. Upper Vaqueros formation; locality 4631..... 85



VAQUEROS FOSSILS.

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PLATE XXX.

PLATE XXX.

VAQUEROS (LOWER MIOCENE) FOSSILS: UPPER HORIZON.

TURRITELLA OCOYANA Conrad.

Page.

Figure 1. Back of imperfect specimen, longitude 50 mm., natural size. Catalogue No. 165593, U.S.N.M. Vaqueros formation; locality 4631. This is one of the most characteristic fossils of the Vaqueros, especially in the San Joaquin Valley and in southern California. 85

2. Back of two whorls of an exceedingly large specimen, altitude 42 mm., natural size. Catalogue No. 165574, U.S.N.M. Upper Vaqueros formation; locality 4631.

VENUS PERTENUIS Gabb.

Figure 3. Exterior of right valve, longitude 88 mm., natural size. Catalogue No. 165597, U.S.N.M. Upper Vaqueros formation; locality 4631. This species is believed to be characteristic of the Miocene..... 85

PHACOIDES ACUTILINEATUS Conrad.

Figure 4. Exterior of left valve, altitude 35.5 mm., natural size. Catalogue No. 165564, U.S.N.M. Upper Vaqueros formation; locality 4803. This species ranges from the lower Miocene to the lower Pliocene fauna. Formerly called *Lucina acutilineata*..... 86

AGASOMA SANTACRUZANA Arnold.

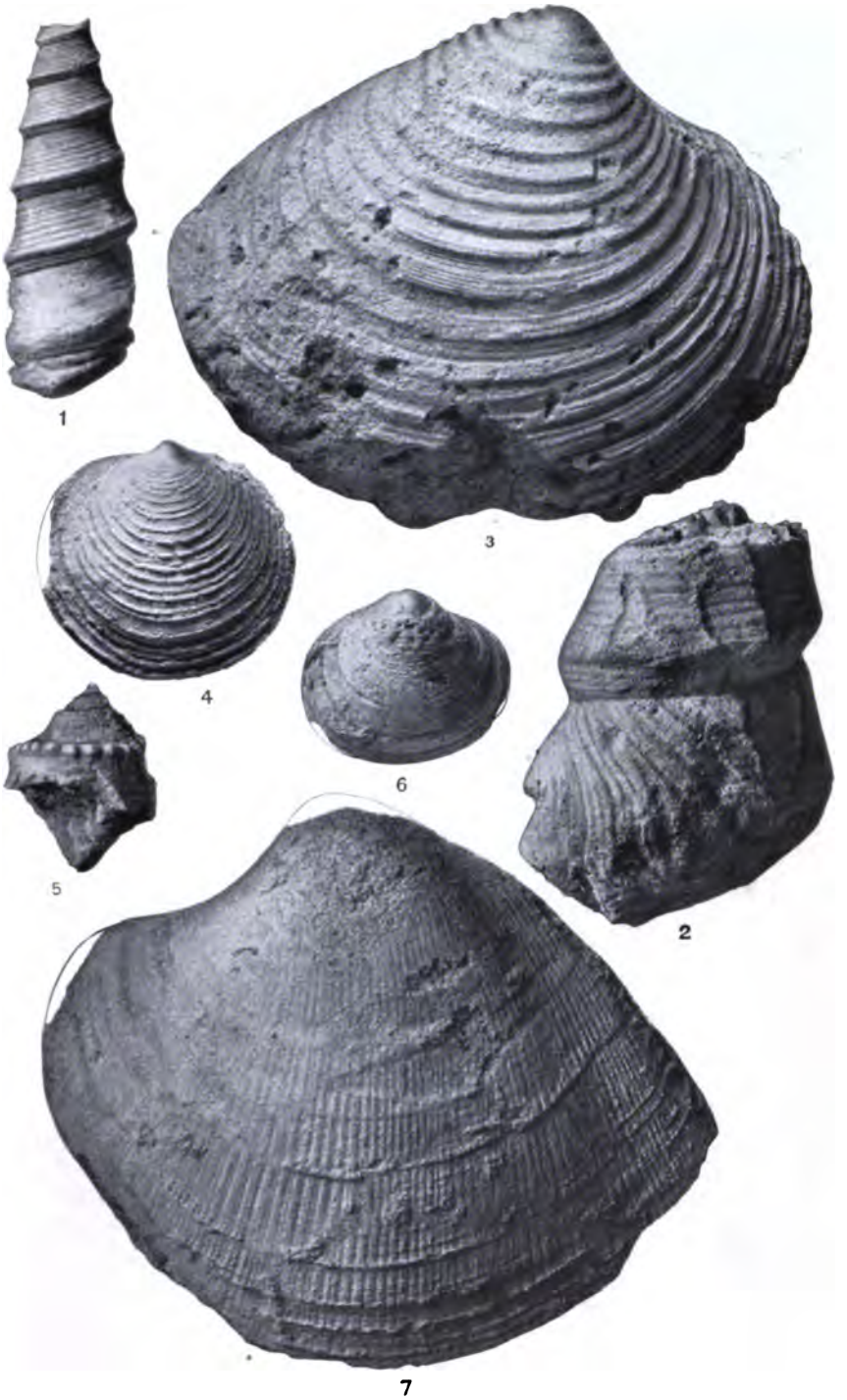
Figure 5. Front of imperfect specimen, consisting of spire and part of body whorl, latitude 19 mm., natural size. Catalogue No. 165609, U.S.N.M. Vaqueros formation; locality 4631. This species is believed to be characteristic of the Vaqueros..... 85

CORBICULA DUMBLEI F. M. Anderson.

Figure 6. Exterior of right valve, longitude 28 mm., natural size. Catalogue No. 165581, U.S.N.M. Vaqueros formation; locality 4628. This species is found abundantly in the Vaqueros oil sand where it outcrops in Anticline Canyon southwest of Coalinga..... 85

CHIONE TEMBLORENSIS F. M. Anderson.

Figure 7. Exterior of imperfect and decorticated left valve, longitude 92 mm., natural size. Catalogue No. 165612, U.S.N.M. Upper Vaqueros formation; locality 4631. This species, which is characterized by its central beaks and narrow form, is believed to be characteristic of the Vaqueros formation..... 85



VAQUEROS FOSSILS.

PLATE XXXI.

PLATE XXXI.

VAQUEROS (LOWER MIOCENE) FOSSILS: UPPER HORIZON.

DOSINIA PONDEROSA Gray.

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Figure 1. Exterior of left valve, altitude 78 mm., natural size. Catalogue No. 165660, U.S.N.M. Upper Vaqueros formation; locality 4631. This species ranges from the lower Miocene to the Recent fauna..... 85

CARDIUM (TRACHYCARDIUM) VAQUEROSENSIS Arnold.

Figure 2. Exterior of imperfect right valve, altitude 98 mm., natural size. Catalogue No. 165598, U.S.N.M. Upper Vaqueros formation; locality 4631..... 85

CONUS OWENIANUS F. M. Anderson.

Figure 3. Front, altitude 16 mm., natural size. Catalogue No. 165606, U.S.N.M. Upper Vaqueros formation; locality 4631. This species, which is characterized by spiral striations, is believed to be characteristic of the Vaqueros..... 85

OCINEBRA TOPANGENSIS Arnold.

Figure 4. Back, longitude 25 mm., natural size. Catalogue No. 165608, U.S.N.M. Upper Vaqueros formation; locality 4631. This species, which is also found in the Santa Monica Mountains, is believed to be characteristic of the Vaqueros formation..... 85

CANCELLARIA ANDERSONI Arnold.

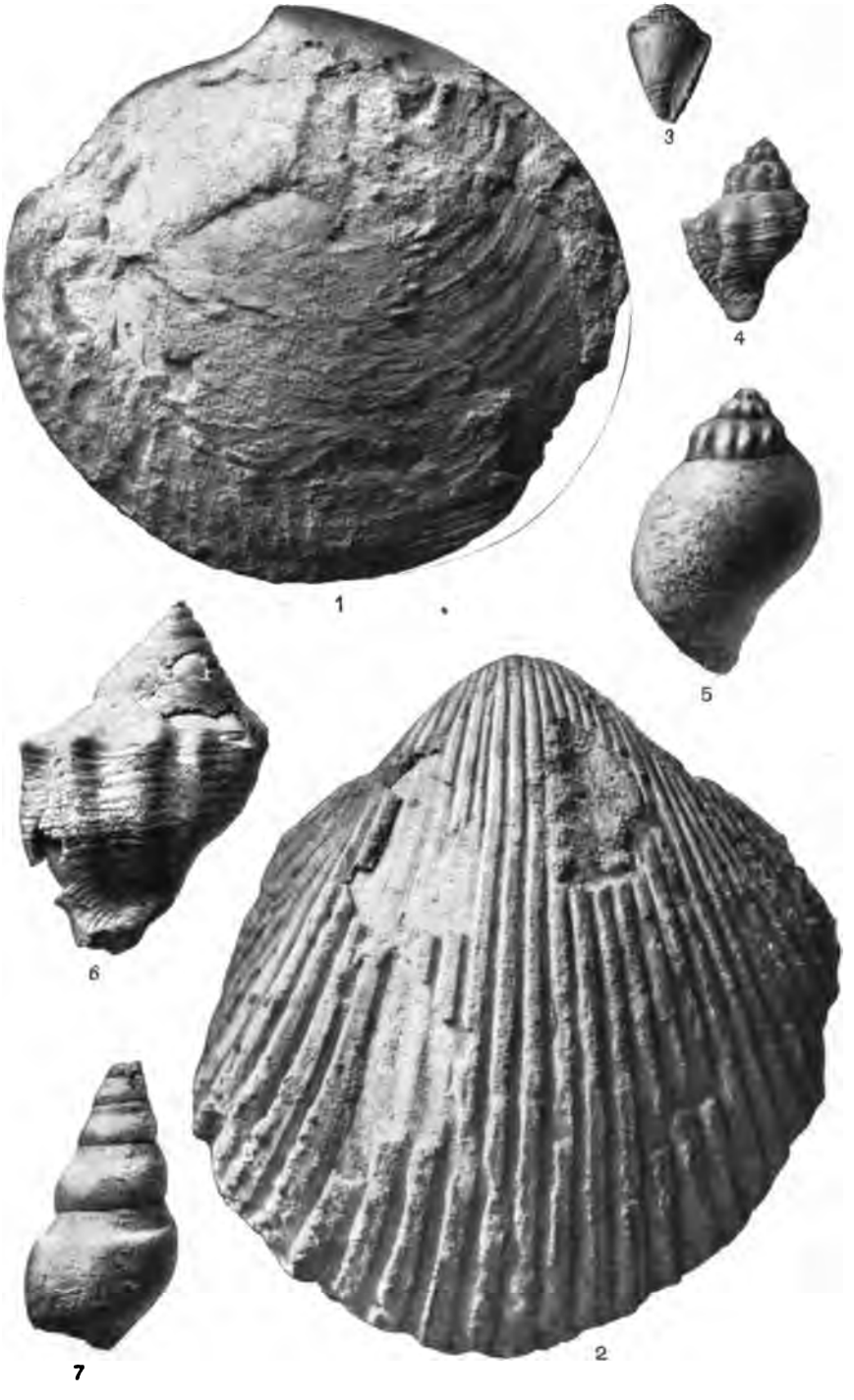
Figure 5. Back, longitude 21 mm., × 2. Type, catalogue No. 165607, U.S.N.M. Upper Vaqueros formation; locality 4631..... 85

CANCELLARIA VETUSTA Gabb.

Figure 6. Back, longitude 51 mm., natural size. Catalogue No. 165600, U.S.N.M. Upper Vaqueros formation; locality 4631. This species is believed to be characteristic of the Vaqueros..... 85

PLEUROTOMA (BATHYTOMA) PIERCEI Arnold.

Figure 7. Back of imperfect specimen, altitude 39.5 mm., natural size. Type, catalogue No. 165578, U.S.N.M. Upper Vaqueros formation; locality 4631..... 85



VAQUEROS FOSSILS.

PLATE XXXII.

PLATE XXXII.

SANTA MARGARITA (UPPER MIDDLE MIOCENE) FOSSILS.

TAMIOSOMA GREGARIA Conrad.

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Figure 1. Side, group of individuals, maximum altitude 187 mm., one-half natural size. Catalogue No. 165618, U.S.N.M. Santa Margarita (?) formation; locality 4766. This unique form, which is closely related to the barnacles, is believed to be characteristic of the upper Miocene and is usually found abundantly in the fossiliferous portions of the Santa Margarita (?) formation..... 94

HINNITES GIGANTEUS Gray.

Figure 2. Exterior of right valve, longitude 58 mm., natural size. Catalogue No. 165586, U.S.N.M. Santa Margarita (?) formation; locality 4651. This species ranges from the middle Miocene to the Recent fauna. The specimen figured is an immature, fair-sized individual..... 94

PECTEN ESTRELLANUS Conrad.

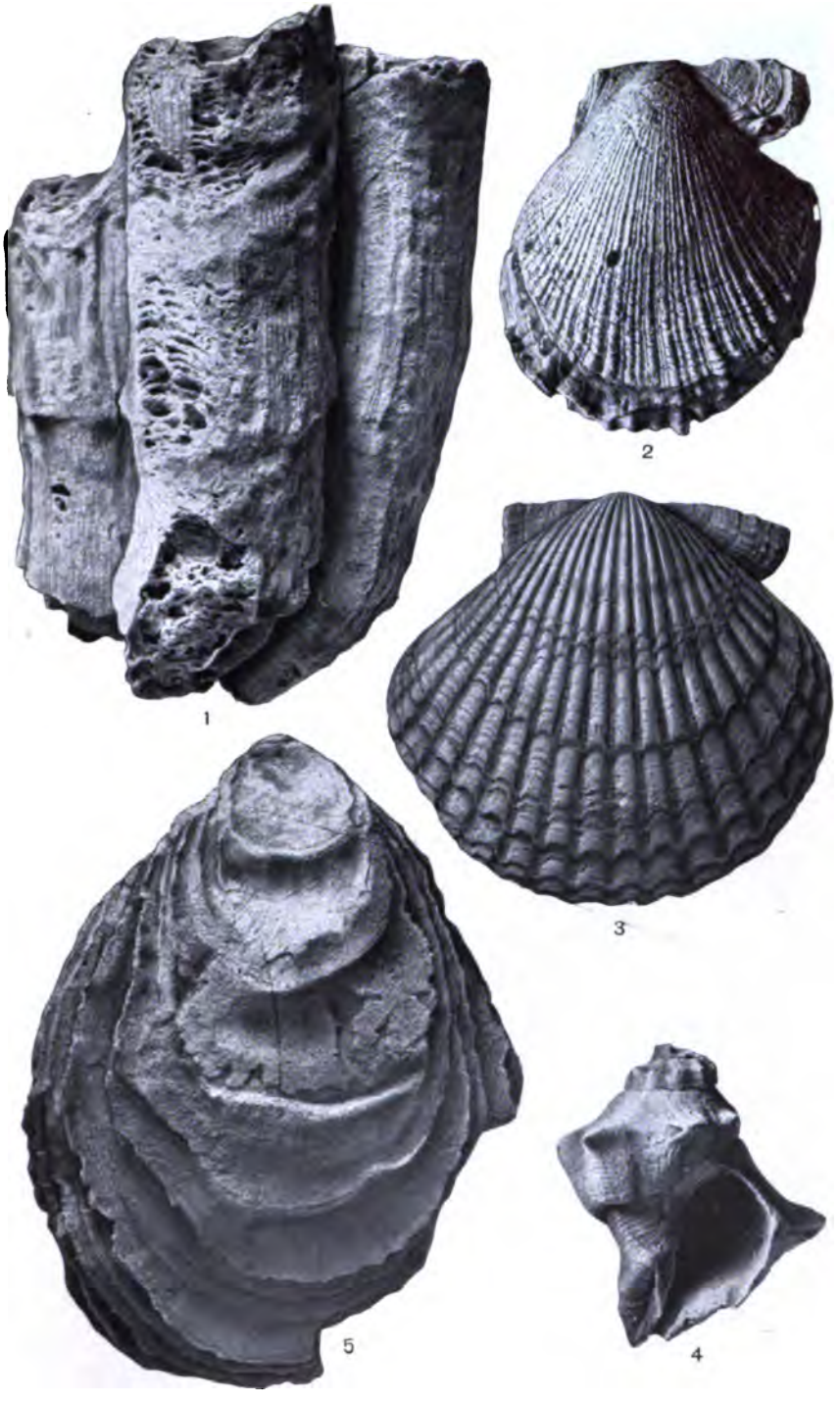
Figure 3. Exterior of right valve, altitude 111 mm., one-half natural size. Catalogue No. 165616, U.S.N.M. Santa Margarita (?) formation; locality 4766. This species is exceedingly common in the Santa Margarita (?) and Jacalitos formations, but may extend into the Vaqueros..... 94

TROPHON (FORRERIA) CARISAENSIS F. M. Anderson.

Figure 4. Front, longitude 41 mm., natural size. Type, catalogue No. 165591, U.S.N.M. Santa Margarita (?) formation; locality 4766. This species is characterized by its moderate size and the spines which are located in the middle of the whorl. It is believed to be characteristic of the Santa Margarita (?) formation..... 94

OSTREA TITAN Conrad.

Figure 5. Exterior of right valve; longitude 174 mm., one-half natural size. Catalogue No. 165617, U.S.N.M. Santa Margarita (?) formation; locality 4766..... 94



. SANTA MARGARITA FOSSILS.

PLATE XXXIII.

PLATE XXXIII.

SANTA MARGARITA (UPPER MIDDLE MIOCENE) AND JACALITOS (UPPER MIOCENE) FOSSILS.

ASTRODAPSIS WHITNEYI Rémond.

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Figure 1. Top of back of imperfect specimen, maximum diameter 76 mm., natural size. Catalogue No. 165594, U.S.N.M. Santa Margarita (?) formation; locality 4766. This species is believed to be characteristic of the Santa Margarita (?) formation in the Coalinga district..... 94

OSTREA TITAN Conrad.

Figure 2. Exterior of left valve, altitude 290 mm., one-half natural size. Catalogue No. 165617, U.S.N.M. Santa Margarita (?) formation; locality 4766. This magnificent *Ostrea* is found abundantly throughout the Miocene, especially in the upper half of the middle Miocene; it sometimes attains a length of 20 inches and a weight of over 20 pounds..... 94

PLIOHIPPUS sp. *a*.

Figure 3. Side, longitude 49 mm., natural size. Catalogue No. 165665, U.S.N.M. Jacalitos formation; NW. ¼ sec. 22, T. 19 S., R. 15 E. The extinct horse, of which this tooth is all that was found, is believed to be characteristic of the upper Miocene..... 98

3a. Crown of same specimen.

THAIS CRISPATUS Chemnitz.

Figure 4. Front of décolleté and otherwise slightly imperfect specimen, longitude 44 mm., natural size. Catalogue No. 165532, U.S.N.M. Upper Jacalitos formation; locality 4763. This species ranges from the upper Miocene to the Recent fauna and is an exceedingly variable species, some specimens being almost smooth, others strongly sculptured. The genus *Thais* has heretofore been commonly known as *Purpura*..... 110

SANTA MARGARITA AND JACALITOS FOSSILS.

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PLATE XXXIV.

PLATE XXXIV.

SANTA MARGARITA (UPPER MIDDLE MIOCENE) AND JACALITOS (UPPER MIOCENE) FOSSILS.

PECTEN CRASSICARDO Conrad.

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Figure 1. Exterior of right valve, altitude 165 mm., one-half natural size. Catalogue No. 165615, U.S.N.M. Santa Margarita (?) formation; locality No. 4766. This species is characterized by its large size, fine radial striations, and lack of prominent intercalary rib. Ranges throughout the Miocene. Is usually more abundant in the middle and upper portions..... 94

MACOMA VANVLECKI Arnold.

Figure 2. Exterior of right valve, longitude 54 mm., natural size. Type, catalogue No. 165576, U.S.N.M. Jacalitos formation; locality 4763. (See Pl. XXXIX, fig. 1)..... 110

SCHIZODESMA ABSCISSA Gabb.

Figure 3. Exterior of right valve, longitude 100 mm., natural size. Catalogue No. 165604, U.S.N.M. Jacalitos formation; locality 4765. This species is believed to be characteristic of the upper Miocene.... 110

SANTA MARGARITA AND JACALITOS FOSSILS.

PLATE XXXV.

PLATE XXXV.

JACALITOS (UPPER MIOCENE) ECHINODERMATA.

ECHINARACHNIUS GIBBSII Rémond.

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Figure 1. Top, longitude 81 mm., natural size. Catalogue No. 165611, U.S.N.M. Jacalitos formation; locality 4747. This large variety is believed to be characteristic of the lower part of the Jacalitos..... 110

2. Bottom of another specimen, longitude 87 mm., natural size. Same locality.

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JACALITOS ECHINODERMATA.

PLATE XXXVI.

PLATE XXXVI.

JACALITOS (UPPER MIOCENE) FOSSILS.

MONIA MACROSCHISMA Deshayes.

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Figure 1. Exterior of left valve, longitude 66 mm., natural size. Catalogue No. 165602, U.S.N.M. Jacalitos formation; locality 4767. This species ranges from upper Miocene to the Recent fauna. Erroneously called *Placunanomia macroschisma* 110

TELLINA ARAGONIA Dall.

Figure 2. Exterior of right valve, longitude 48 mm., natural size. Catalogue No. 165577, U.S.N.M. Jacalitos formation; locality 4765. This species, which was originally described from the Empire formation at Coos Bay, Oregon, is believed to be characteristic of the upper Miocene..... 110

TROPHON (FORRERIA) PONDEROSUM Gabb.

Figure 3. Back of young specimen, longitude 43 mm., natural size. Catalogue No. 165590, U.S.N.M. Etchegoin formation; locality 4642. This species is common in the Jacalitos formation and rare in the Etchegoin 109

CHRYSODOMUS IMPERIALIS Dall.

Figure 4. Back of nearly perfect specimen, longitude 57 mm., natural size. Catalogue No. 165582, U.S.N.M. Upper Jacalitos formation; locality 4767. This species, which is characterized by its broad outline and peculiar reflexed varices, is believed to be characteristic of the upper Miocene. It is found in Oregon, in Santa Cruz County, Cal., and at one or two localities in the Coalinga district 110

TROPHON (FORRERIA) PONDEROSUM Gabb.

Figure 5. Side of imperfect specimen, altitude 86 mm., natural size. Catalogue No. 165562, U.S.N.M. Jacalitos formation; locality 4784.. 110

6. Front of imperfect specimen, altitude 72 mm., natural size. Catalogue No. 165555, U.S.N.M. Jacalitos formation; locality 4765.. 110

JACALITOS FOSSILS.

PLATE XXXVII.

PLATE XXXV.

PLATE XXXVIII.

PLATE XXXVIII.

JACALITOS (UPPER MIOCENE) PELECYPODA.

MACOMA VANVLECKI Arnold.

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Figure 1. Exterior of left valve, longitude 54 mm. Type, catalogue No. 165576, U.S.N.M. Jacalitos formation; locality 4763. (See Pl. XXXIV, fig. 2)..... 110

MACOMA JACALITOSANA Arnold.

Figure 2. Exterior of right valve, longitude 70 mm., natural size. Type, catalogue No. 165613, U.S.N.M. Jacalitos formation; locality 4765.. 110

PAPHIA JACALITOSENSIS Arnold.

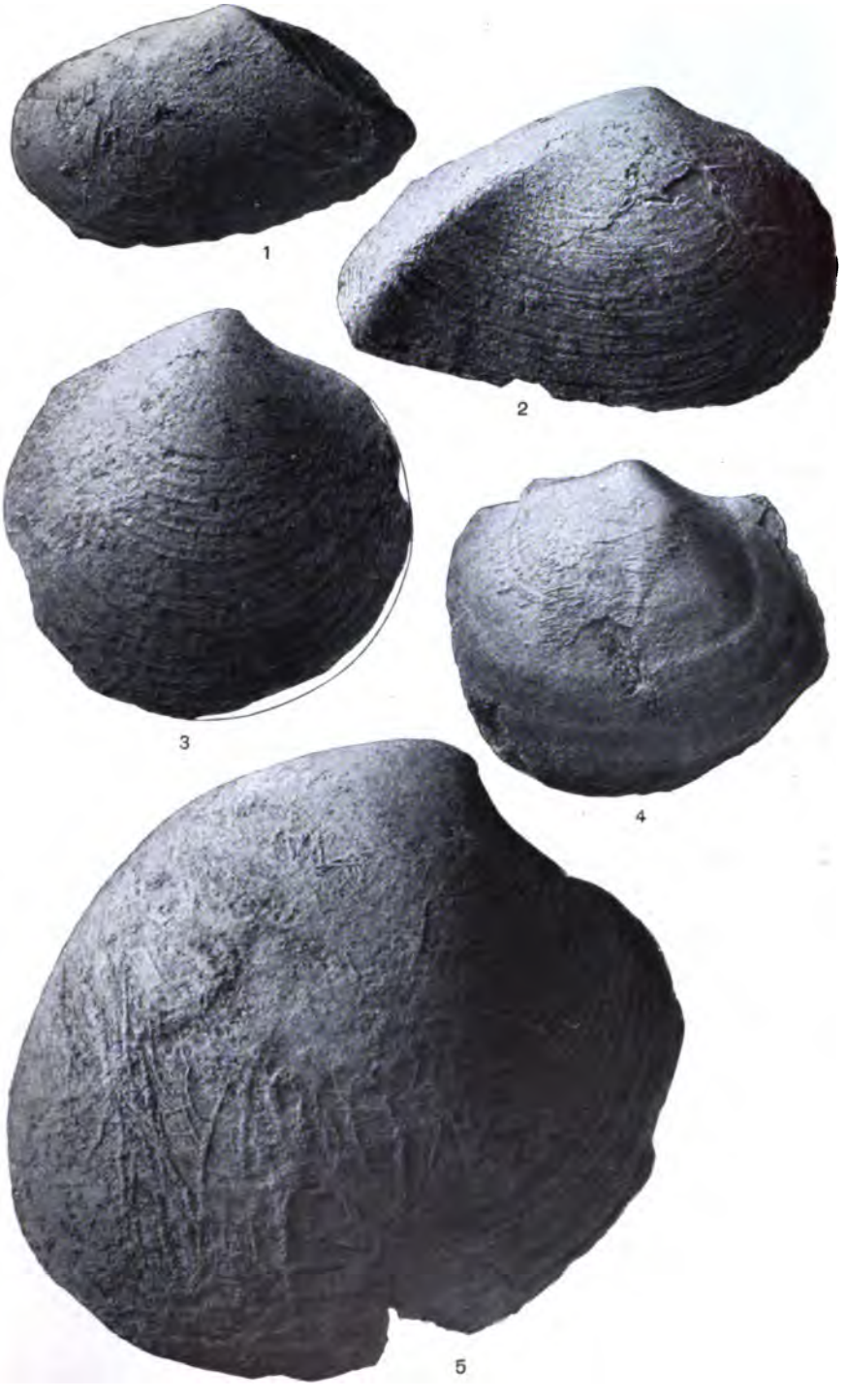
Figure 3. Exterior of right valve, altitude 57 mm., natural size. Type, catalogue No. 165587, U.S.N.M. Jacalitos formation; locality 4765. 110

THRACIA JACALITOSANA Arnold.

Figure 4. Exterior of cast of left valve, longitude 51 mm., natural size. Type, catalogue No. 165579, U.S.N.M. Jacalitos formation; locality 4763..... 110

DOSINIA JACALITOSANA Arnold.

Figure 5. Exterior of right valve, longitude 95 mm., natural size. Type, catalogue No. 165575, U.S.N.M. Jacalitos formation; locality 4763. 110



JACALITOS PELECYPODA.

PLATE XXXIX.

PLATE XXXIX.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

OSTREA ATWOODI Gabb.

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Figure 1. Exterior of left valve, longitude 59 mm., natural size. Catalogue No. 165531, U.S.N.M. Lower Etchegoin formation; locality 4678. This species is believed to be characteristic of the upper Jacalitos and lower Etchegoin formations, or middle portion of upper Miocene..... 126

2. Exterior of right valve, longitude 48 mm. Same locality.

MULINIA DENSATA Conrad.

Figure 3. Exterior of right valve, longitude 65 mm., natural size. Catalogue No. 165559, U.S.N.M. Lower Etchegoin formation; locality 4682. This species ranges throughout the Miocene, but is more commonly found in the upper Miocene. It is sometimes known as *Pseudocardium gabbi* Rémond..... 125

4. Interior of left valve, longitude 75 mm., natural size. Catalogue No. 165559, U.S.N.M. Lower Etchegoin formation; locality 4679... 125

DIPLODONTA PARILIS Conrad.

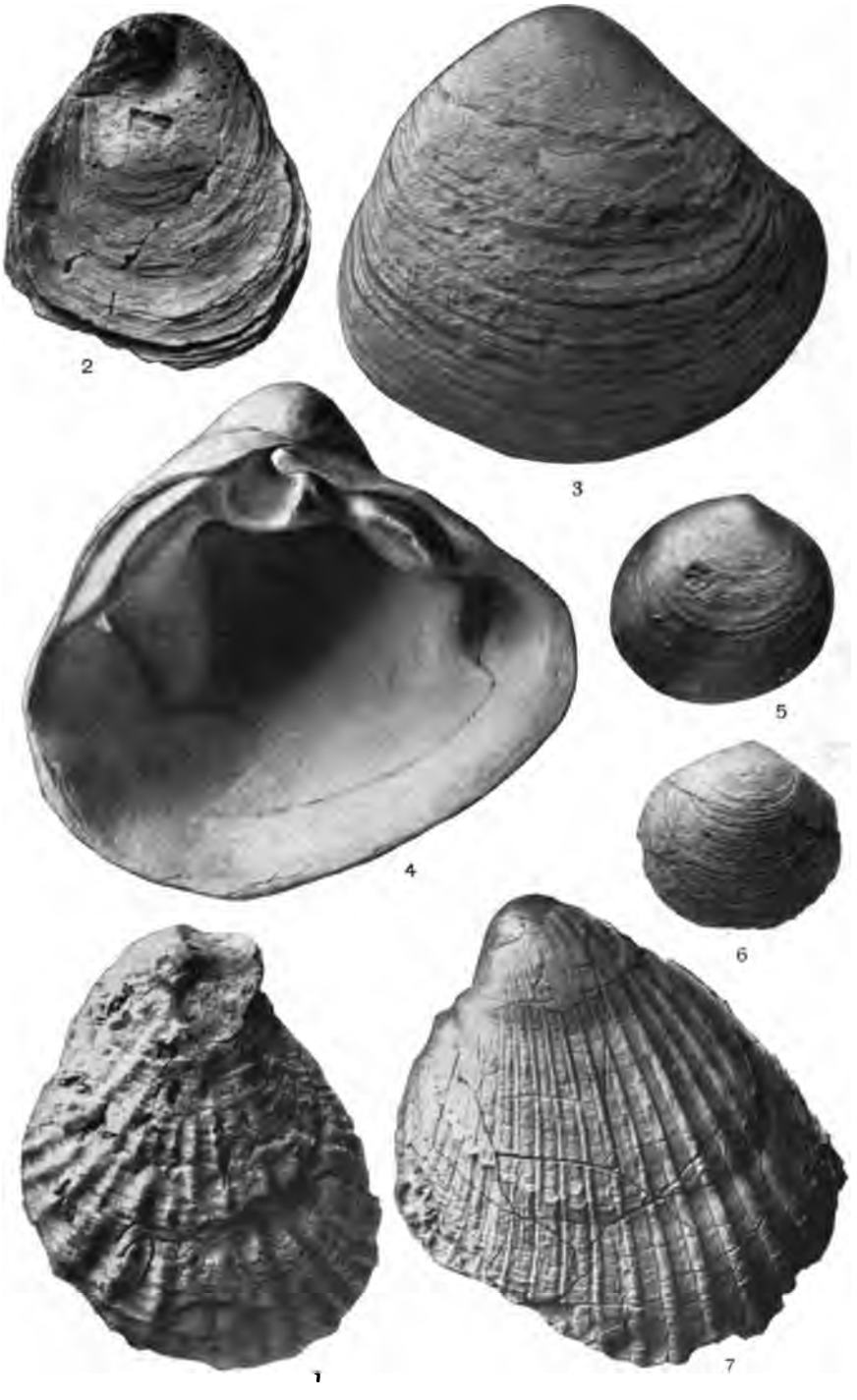
Figure 5. Exterior of right valve, longitude 31 mm., natural size. Catalogue No. 165484, U.S.N.M. Lower Etchegoin formation; locality 4806. This species is believed to be characteristic of the upper Miocene. It is also known from Oregon..... 131

DIPLODONTA HARFORDI F. M. Anderson.

Figure 6. Exterior of right valve, longitude 28 mm., natural size. Catalogue No. 165485, U.S.N.M. Lower Etchegoin formation; locality 4806. This species is believed to be characteristic of the upper Miocene and has so far been recognized only in the Coalinga district..... 131

CARDIUM MEEKIANUM Gabb.

Figure 7. Exterior of decorticated left valve, altitude 70 mm., natural size. Catalogue No. 165542, U.S.N.M. Lower Etchegoin formation; locality 4806. The external surface of this fossil is almost always gone. It is an abundant species in one or two of the layers of the lower Etchegoin, but has a range elsewhere from the upper Miocene to the lower Pliocene..... 131



ETCHEGOIN FOSSILS.

PLATE XL.

PLATE XL.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

ARCA TRILINEATA Conrad.

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Figure 1. Exterior of left valve, longitude 61 mm., natural size. Catalogue No. 165534, U.S.N.M. Lower Etchegoin formation; locality 4665. This species, which is variable both in outline and number and sculpture of ribs, ranges from the upper Miocene to the Pliocene. It is abundant in the upper Miocene and later marine faunas in the Coalinga district..... 125

1a. Umbones of same specimen.

THAIS ETCHEGOINENSIS Arnold.

Figure 2. Front of slightly décolleté specimen, longitude 38 mm., natural size. Type, catalogue No. 165533, U.S.N.M. Lower Etchegoin formation; locality No. 4697. The genus *Thais* was formerly known as *Purpura*..... 130

PAPHIA TENERRIMA Carpenter.

Figure 3. Exterior of left valve, longitude 83 mm., natural size. Catalogue No. 165544, U.S.N.M. Middle Etchegoin formation; locality 4664. This species is abundant in the middle Etchegoin beds on White Creek and Anticline Ridge. It ranges from the upper Miocene to the Recent fauna..... 126

PANOPEA GENEROSA Gould.

Figure 4. Exterior of right valve, longitude 104 mm., natural size. Catalogue No. 165556, U.S.N.M. Upper Etchegoin formation; locality 4658. This species ranges from the lower Miocene to the Recent fauna..... 126

ETCHEGOIN FOSSILS.

PLATE XLI.

PLATE XLI.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

ECHINARACHNIUS GIBBSII Rémond var. ASHLEYI Arnold.

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Figure 1. Top, longitude 60 mm., natural size. Catalogue No. 165548, U.S.N.M. Upper Jacalitos formation; locality 4767. An abundant form at this locality; also abundant in the Santa Maria district..... 110

ECHINARACHNIUS GIBBSII Rémond.

Figure 2. Top, longitude 54 mm. Catalogue No. 165547, U.S.N.M. Locality 4661. A relatively narrower specimen than that shown in Plate XLII, figure 7..... 125

GLYCYMERIS COALINGENSIS Arnold.

Figure 3. Exterior of decorticated right valve, longitude 42 mm., natural size. Type, catalogue No. 165526, U.S.N.M. Lower Etchegoin formation; locality 4806. This genus was formerly known as *Pectunculus*..... 131

MACTRA ALBARIA Conrad.

Figure 4. Exterior of an imperfect right valve from which a portion of the anterior extremity has been eroded; altitude 63 mm., natural size. Catalogue No. 165552, U.S.N.M. Lower Etchegoin formation; locality 4665. This species, which is believed to be characteristic of the upper Miocene, is found abundantly in Oregon, but only a few specimens were obtained in the Coalinga district..... 125

MYTILUS (MYTILOCONCHA) COALINGENSIS Arnold.

Figure 5. Exterior of imperfect left valve, altitude 100 mm., natural size. Paratype, catalogue No. 165557, U.S.N.M. Lower Etchegoin formation; locality 4658..... 125

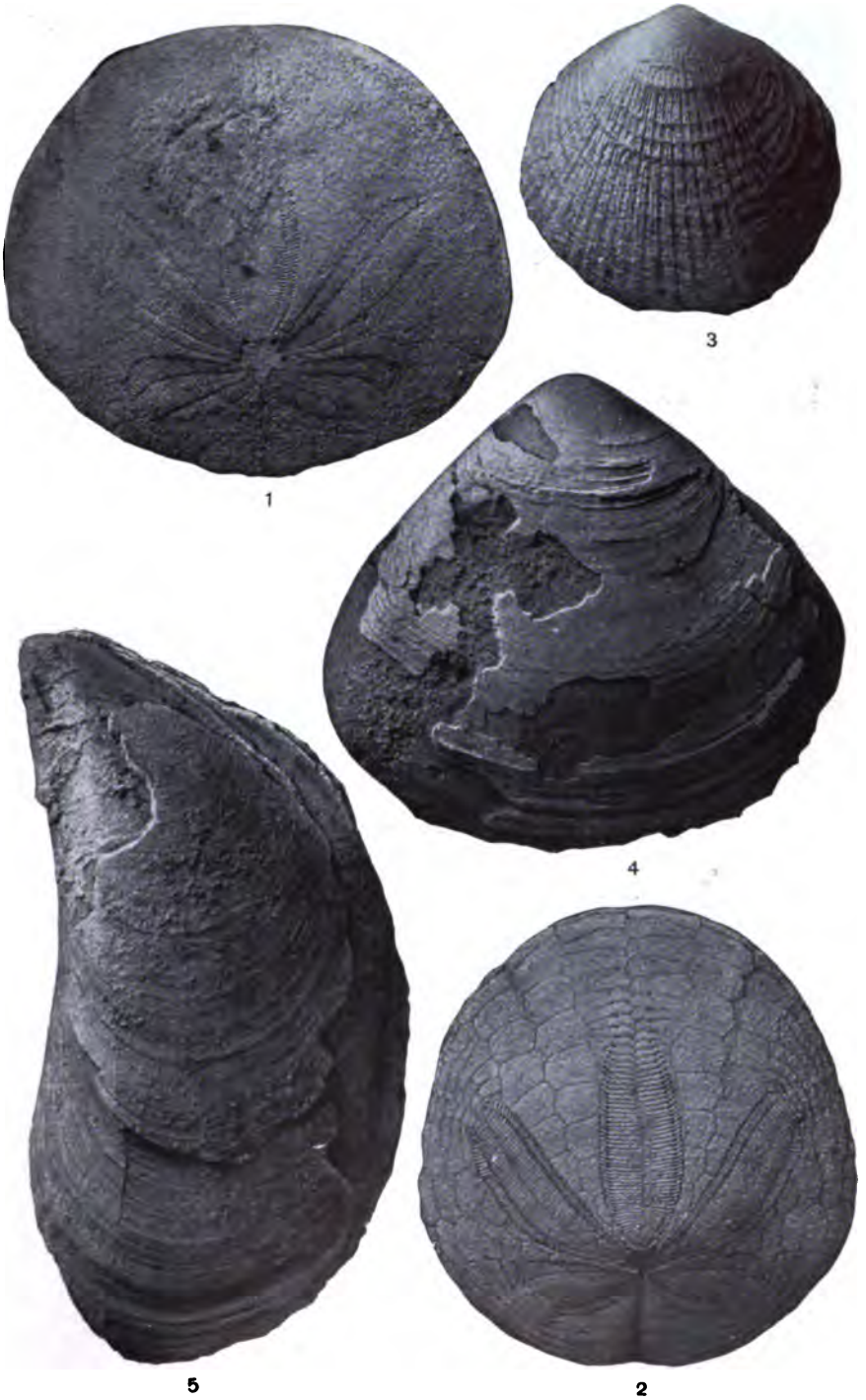

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PLATE XLII.

PLATE XLII.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

MACOMA SECTA Conrad.

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Figure 1. Exterior of left valve, longitude 75 mm., natural size. Catalogue No. 165592, U.S.N.M. Etchegoin formation; locality 4806. This species ranges from the upper Miocene to the Recent fauna. 131

NEVERITA RECLUZIANA Petit.

Figure 2. Front view of decorticated and slightly imperfect specimen, altitude 36 mm., natural size. Catalogue No. 165486, U.S.N.M. Upper Etchegoin formation; locality 4710. This species ranges from the upper Miocene to the Recent fauna..... 130

GLYCYMERIS SEPTENTRIONALIS Middendorf.

Figure 3. Exterior of left valve, longitude 24 mm. Catalogue No. 165527, U.S.N.M. Lower part of the Etchegoin formation; locality 4806. This genus was formerly known as *Pectunculus*..... 131

3a. Interior view of same specimen.

MODIOLUS RECTUS Conrad.

Figure 4. Exterior of right valve from which the outer surface of the shell has been removed, longitude 86 mm., natural size. Catalogue No. 165535, U.S.N.M. Lower Etchegoin formation; locality 4698. This species ranges from the upper Miocene to the Recent and is characterized by its angular posterior outline..... 128

NEVERITA RECLUZIANA Petit var. ALTA Dall.

Figure 5. Front of slightly imperfect specimen, altitude 28 mm., natural size. Catalogue No. 165489, U.S.N.M. Upper Etchegoin formation; locality 4709. This variety ranges from the upper Miocene to the Recent fauna..... 130

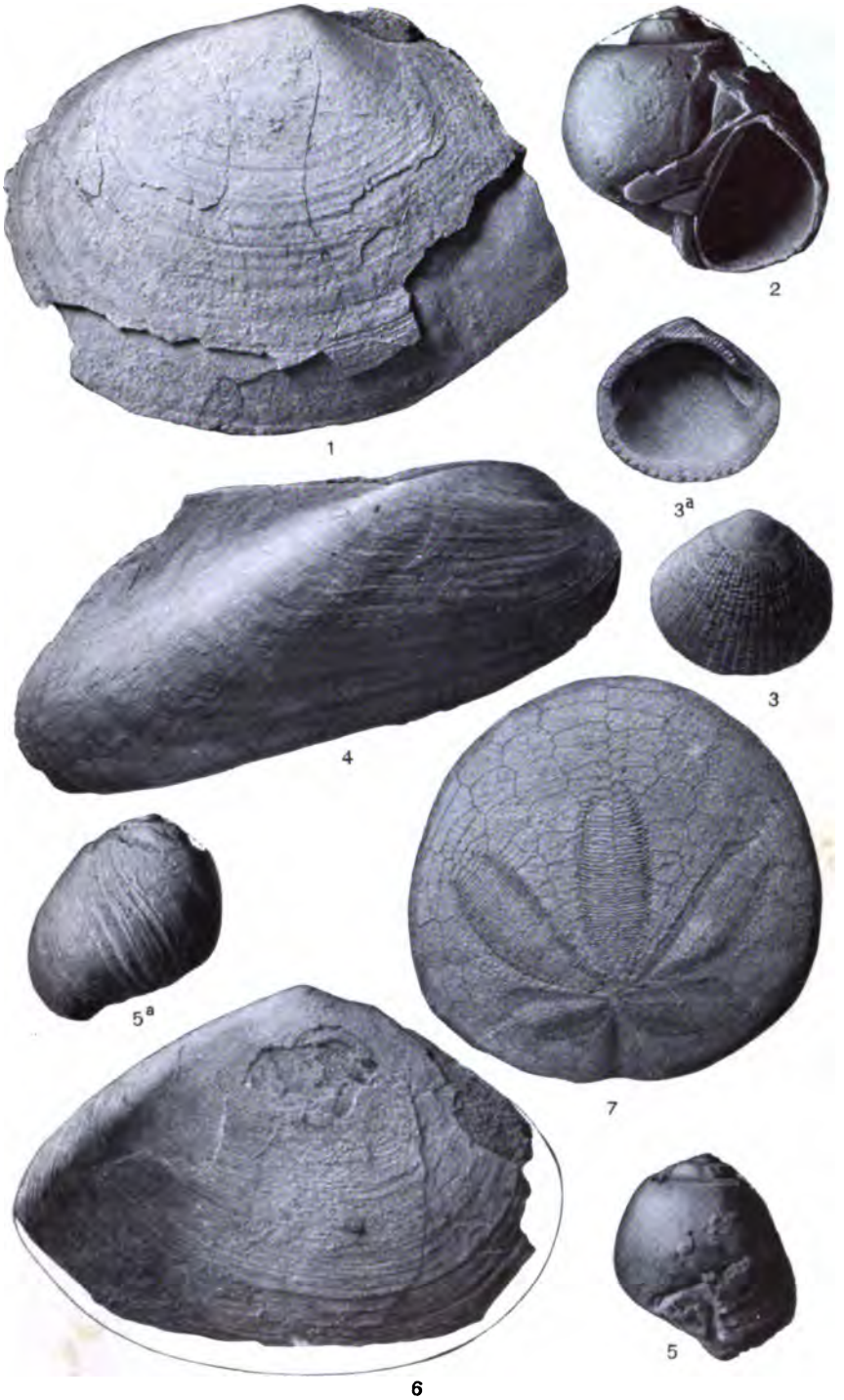
5a. Back of same specimen.

MACOMA NASUTA Conrad.

Figure 6. Exterior of slightly imperfect right valve, longitude 70 mm., natural size. Catalogue No. 165514, U.S.N.M. Lower part of the Etchegoin formation; locality 4756. This species ranges from the lower Miocene to the Recent fauna..... 131

ECHINARACHNIUS GIBBSII Rémond.

Figure 7. Top, longitude 61 mm., natural size. Catalogue No. 165547, U.S.N.M. Lower Etchegoin formation; locality 4661. This figure illustrates a typical undistorted specimen. The specimens found in this district are usually more or less distorted. The species ranges through the Jacalitos and Etchegoin formations. (See Pl. XLI, fig. 2)..... 125



ETCHEGOIN FOSSILS.

PLATE XLIII.

PLATE XLIII.

JACALITOS (EARLY UPPER MIOCENE) AND ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

THAIS KETTLEMANENSIS Arnold.

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Figure 1. Front of decorticated and slightly imperfect specimen, altitude 82 mm., natural size. Type, catalogue No. 165585, U.S.N.M. Jacalitos formation; locality 4763..... 110

1a. Back of same specimen.

CRYPTOMYA QUADRATA Arnold.

Figure 2. Exterior of right valve, longitude 35 mm., natural size. Type, catalogue No. 165525, U.S.N.M. Lower Etchegoin formation; locality 4665..... 125

2a. Exterior of left valve of same specimen.

MULINIA DENSATA Conrad.

Figure 3. Front of both valves, altitude 50 mm., natural size. Catalogue No. 165554, U.S.N.M. Lower Etchegoin formation; locality 4754. This species is usually confined to the upper Miocene, although it is known to extend down into the Vaqueros. This species is sometimes listed as *Pseudocardium gabbi* Rémond..... 131

SAXIDOMUS NUTTALLI Conrad.

Figure 4. Exterior of right valve 105 mm., two-thirds natural size. Catalogue No. 165529, U.S.N.M. Upper part of Jacalitos formation; locality 4656. This species ranges from the upper Miocene to the Recent fauna..... 126

JACALITOS AND ETCHEGOIN FOSSILS.

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PLATE XLIV.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

LUNATIA LEWISII Gould.

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Figure 1. Front of slightly imperfect internal cast which, however, shows the general outline of the shell; altitude 90 mm., natural size. Catalogue No. 165541, U.S.N.M. Upper Etchegoin formation; locality 4665. This species ranges from the upper Miocene to the Recent fauna..... 127

PLEUROTOMA COALINGENSIS Arnold.

Figure 2. Front, longitude 20 mm., × 2. Type, catalogue No. 165509, U.S.N.M. Upper Etchegoin formation; locality 4806..... 133

TURRITELLA VANVLECKI Arnold.

Figure 3. Back of décolleté and otherwise somewhat imperfect specimen; longitude 57 mm., natural size. Type, catalogue No. 165496, U.S.N.M. Middle Etchegoin formation; locality 4658..... 127

TROPHON (FORRERIA) COALINGENSE Arnold.

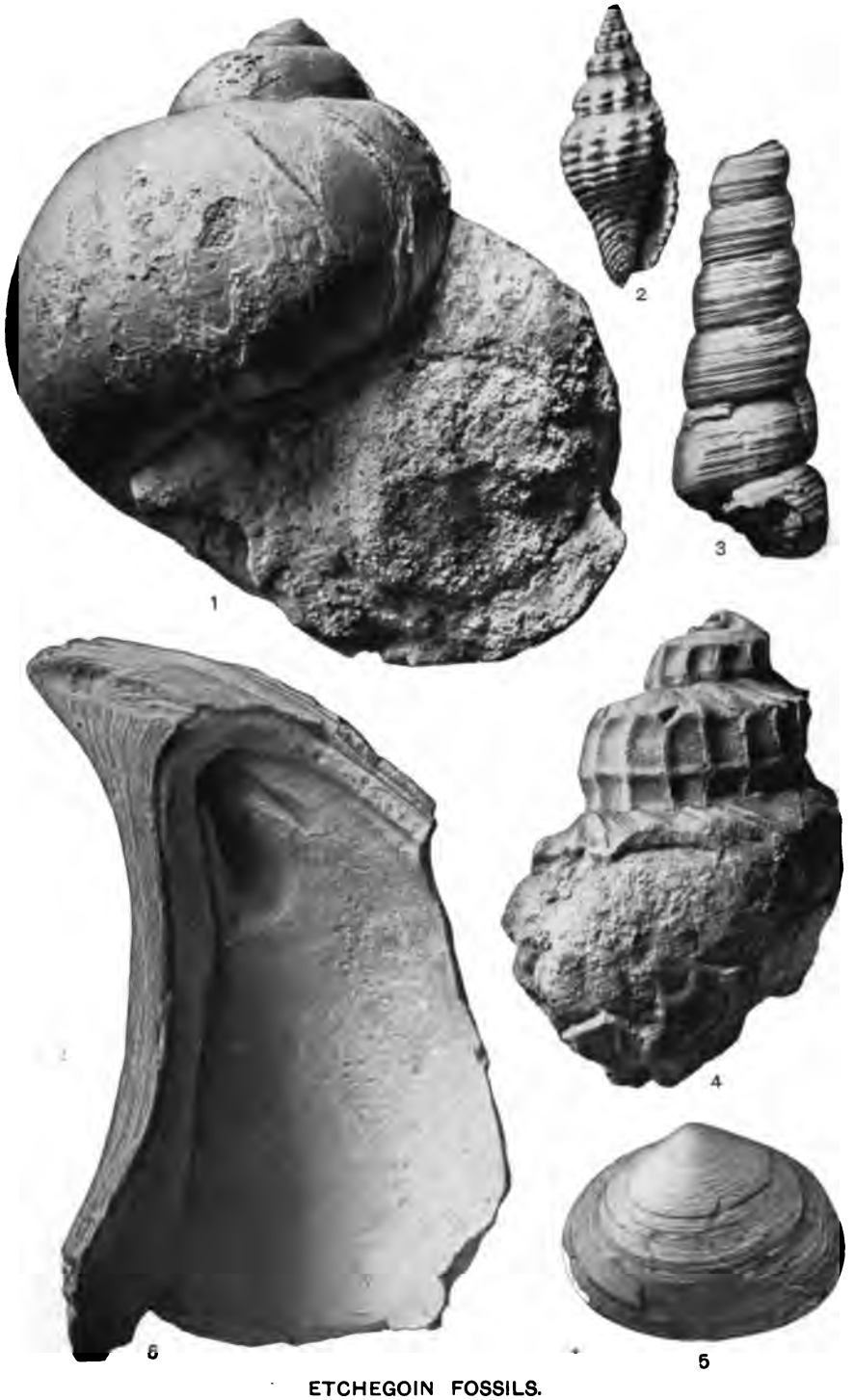
Figure 4. Back of imperfect specimen, longitude 65 mm., natural size. Type catalogue No. 165540, U.S.N.M. Upper Etchegoin formation; locality 4857..... 133

CRYPTOMYA OVALIS Conrad.

Figure 5. Exterior of left valve, longitude 37 mm., natural size. Catalogue No. 165589, U.S.N.M. Etchegoin formation; locality 4758. This specimen appears to be intermediate between the typical *Cryptomya ovalis* Conrad and *Cryptomya quadrata* Arnold..... 131

MYTILUS (MYTILOCONCHA) COALINGENSIS Arnold.

Figure 6. Exterior of umbonal region of a moderate-sized right valve, longitude 105 mm., natural size. Type, catalogue No. 165551, U.S.N.M. Lower Etchegoin formation; locality 4656..... 125



ETCHEGOIN FOSSILS.

PLATE XLV.

PLATE XLV.

ETCHEGOIN (UPPER MIOCENE) FOSSILS.

PECTEN (PATINOPECTEN) OWENI Arnold.

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Figure 1. Exterior of right valve, anterior ear slightly broken, altitude 85 mm., slightly reduced. Type; Coll. Univ. California. Foxin's ranch, Santa Barbara County. A characteristic species in the upper Miocene.

CREPIDULA PRINCEPS Conrad.

Figure 2. View of interior; longitude 106 mm., slightly reduced. Catalogue No. 165315, U.S.N.M. Packard's Hill, Santa Barbara. Found throughout the Miocene and Pliocene in California.

ASTRANGIA COALINGENSIS Vaughan.

Figure 3. View of top of group of specimens, maximum altitude 20 mm., × 3. Type, catalogue No. 165666, U.S.N.M. Upper Etchegoin formation; locality 4710. This species is believed to be characteristic of the upper Miocene..... 128

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ETCHEGOIN FOSSILS.

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PLATE XLVI.

PLATE XLVI.

ETCHEGOIN UPPER MIOCENE) FOSSILS: UPPER HORIZON.

SIGARETUS SCOPULOSUS Conrad.

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Figure 1. Top, maximum diameter 36 mm., natural size. Catalogue No. 165524, U.S.N.M. Upper Etchegoin formation; locality 4662. This species ranges from the Oligocene to the lower Pliocene.... 127

PLACUNANOMIA CALIFORNICA Arnold.

Figure 2. Exterior of right valve, altitude 66 mm., natural size. Type, catalogue No. 165546, U.S.N.M. Upper Etchegoin formation; locality 4715..... 129

2a. Interior of same specimen.

3. Interior of left valve, paratype, altitude 67 mm., natural size.

OSTREA VESPERTINA Conrad.

Figure 4. Exterior of left valve, longitude 57 mm., natural size. Catalogue No. 165536, U.S.N.M. Upper Etchegoin formation; locality 4715.. 129

5. Right valve, longitude 67 mm. Same locality.

ETCHEGOIN FOSSILS.

PLATE XLVII.

PLATE XLV.

Bulbous Growth on Fish Skeleton.

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Figure 8. Grooved base, longitude 40 mm., natural size. Catalogue No. 165494, U.S.N.M. Tulare formation; locality 4731..... 153

Carcharodon arnoldi Jordan.

Figure 9. Back, longitude 50 mm., natural size. Catalogue No. 165488, U.S.N.M. Upper Etchegoin formation; locality 4709. This extinct species of shark is believed to be characteristic of the upper Miocene and lower Pliocene..... 130

PLATE XLVIII.

PLATE XLVIII.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: UPPER HORIZON.

PECTEN COALINGAENSIS Arnold.

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Figure 1. Exterior of right valve, longitude 58 mm., natural size. Catalogue No. 165530, U.S.N.M. Upper part of Etchegoin formation; locality 4710. This species is believed to be characteristic of the upper part of the Etchegoin formation at the top of the Miocene..... 132

2. Left valve, longitude 55 mm., natural size. Same locality.

PECTEN (PLAGIOCTENIUM) DESERTI Conrad.

Figure 3. Exterior of right valve, altitude 43 mm., natural size. Catalogue No. 165518, U.S.N.M. Upper Etchegoin formation; locality 4715.. 132

4. Exterior of left valve, longitude 37 mm., natural size. Same locality.

CHAMA PELLUCIDA Sowerby.

Figure 5. Exterior of left valve, altitude 42 mm., natural size. Catalogue No. 165482 U.S.N.M. Upper Etchegoin formation; locality 4710. This species ranges from the upper Miocene to Recent, but is found in the Coalinga district only in the upper Etchegoin..... 131

6. Exterior of right valve; altitude 24 mm., natural size. Catalogue No. 165482, U.S.N.M. Locality same as last.

TRANSENNELLA CALIFORNICA Arnold.

Figure 7. Exterior of right valve, longitude 5.5 mm., × 5. Type, catalogue No. 165553, U.S.N.M. Upper Etchegoin formation; locality 4715.. 132

7a. Interior of same specimen.

PAPHIA STALEYI? Gabb.

Figure 8. Right valve of young specimen, longitude 8.5 mm., × 3. Catalogue No. 165516, U.S.N.M. Upper Etchegoin formation; locality 4715. This species is believed to be characteristic of the upper Miocene and Pliocene. Formerly called *Tapes staleyi*..... 132

CHRYSODOMUS PORTOLAENSIS Arnold.

Figure 9. Front, longitude 64 mm., natural size. Type, catalogue No. 165473, U.S.N.M. Etchegoin formation; locality 4665. This species is believed to be characteristic of the upper Miocene, and is found abundantly in the lower Purisima formation near Portola in San Mateo County and in several localities farther south 126

CANCELLARIA TRITONIDEA Gabb.

Figure 10. Front, longitude 78 mm., natural size. Catalogue No. 165561, U.S.N.M. Upper San Pedro formation, San Pedro, California. This species is believed to range from the upper Miocene to the Pleistocene. The specimen figured is from the type locality.

ETCHEGOIN FOSSILS.

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PLATE XLIX.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: UPPER HORIZON.

PECTEN (CHLAMYS) WATTSI Arnold.

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Figure 1. Exterior of right valve, altitude 61 mm., natural size. Catalogue No. 165550, U.S.N.M. Upper Etchegoin formation; locality 4712. This specimen is also from the type locality. The species ranges from the upper Miocene to the lower Pliocene and is found in the Coalinga district only in the upper Etchegoin..... 132

2. Exterior of left valve, altitude 76 mm., natural size. Same locality.

PECTEN NUTTERI Arnold.

Figure 3. Exterior of right valve, altitude 67 mm., natural size. Catalogue No. 165549, U.S.N.M. Upper Etchegoin formation; locality 4712. This specimen is from the type locality of the species, where it is moderately abundant. It is believed to be characteristic of the upper Miocene and possibly lower Pliocene..... 132

4. Exterior of left valve, altitude 63 mm. Same locality.

TEREBRATALIA SMITHI Arnold.

Figure 5. Exterior of dorsal valve showing beak of ventral valve, altitude of former 22 mm., natural size. Catalogue No. 165512, U.S.N.M. Upper Etchegoin formation; locality 4758. This brachiopod is very abundant in the *Pecten coalingaensis* horizon..... 131

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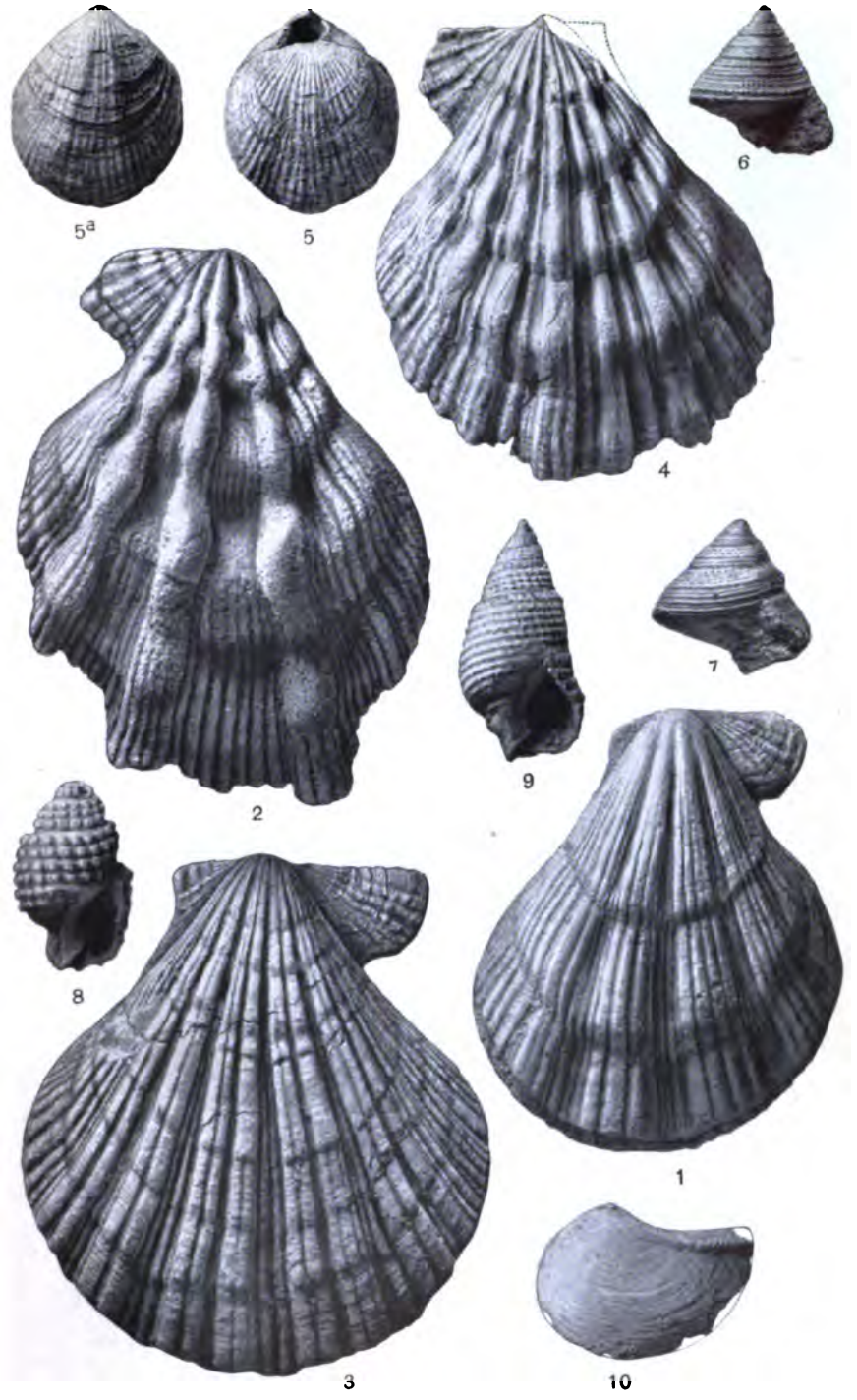
Figure 6. Front of slightly distorted specimen, altitude 18.5 mm., natural size. Type, catalogue No. 165500, U.S.N.M. Upper Etchegoin formation; locality 4758..... 132

CALLIOSTOMA COALINGENSIS Arnold.

Figure 7. Front view of slightly distorted specimen, altitude 21 mm., natural size. Type, catalogue No. 165499, U.S.N.M. Upper Etchegoin formation; locality 4758..... 132

NASSA CALIFORNIANA Conrad.

Figure 8. Front of a slightly imperfect young and unusually nodose specimen, altitude 13.5 mm., × 2. Catalogue No. 165508, U.S.N.M. Upper Etchegoin formation; locality 4806. This species ranges from the upper Miocene to the Pleistocene and may possibly have living representatives. This nodose form is apparently characteristic of the upper Miocene..... 133



ETCHEGOIN FOSSILS.

NASSA CALIFORNIANA Conrad var. COALINGENSIS Arnold.

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Figure 9. Front, altitude 32 mm., natural size. Type, catalogue No. 165511, U.S.N.M. Upper Etchegoin formation; locality 4758..... 133

CLIDIOPHORA PUNCTATA Conrad.

Figure 10. Exterior of left valve, longitude 28 mm., natural size. Catalogue No. 165497, U.S.N.M. Upper Etchegoin formation; locality 4806. This species, in which the right valve is somewhat flatter than the left, ranges from the upper Miocene to Recent fauna.... 131

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PLATE L.

ETCHEGOIN (UPPER MIOCENE) ECHINODERMATA: UPPER HORIZON.

SCUTELLA PERRINI Weaver.

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2. Bottom, longitude 45 mm., natural size. Catalogue No. 165560, U.S.N.M. Same locality.

ASTRODAPSIS? sp. *a*.

Figure 3. Top, longitude 28 mm., × 2. Catalogue No. 165701, U.S.N.M. Upper Etchegoin formation; locality 4712. A common form at this horizon..... 128

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ECHINARACHNIUS GIBBSII Rémond.

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Figure 5. Top of young specimen, longitude 10.5 mm., × 2. Catalogue No. 165538, U.S.N.M. Upper Etchegoin formation; locality 4708. 128

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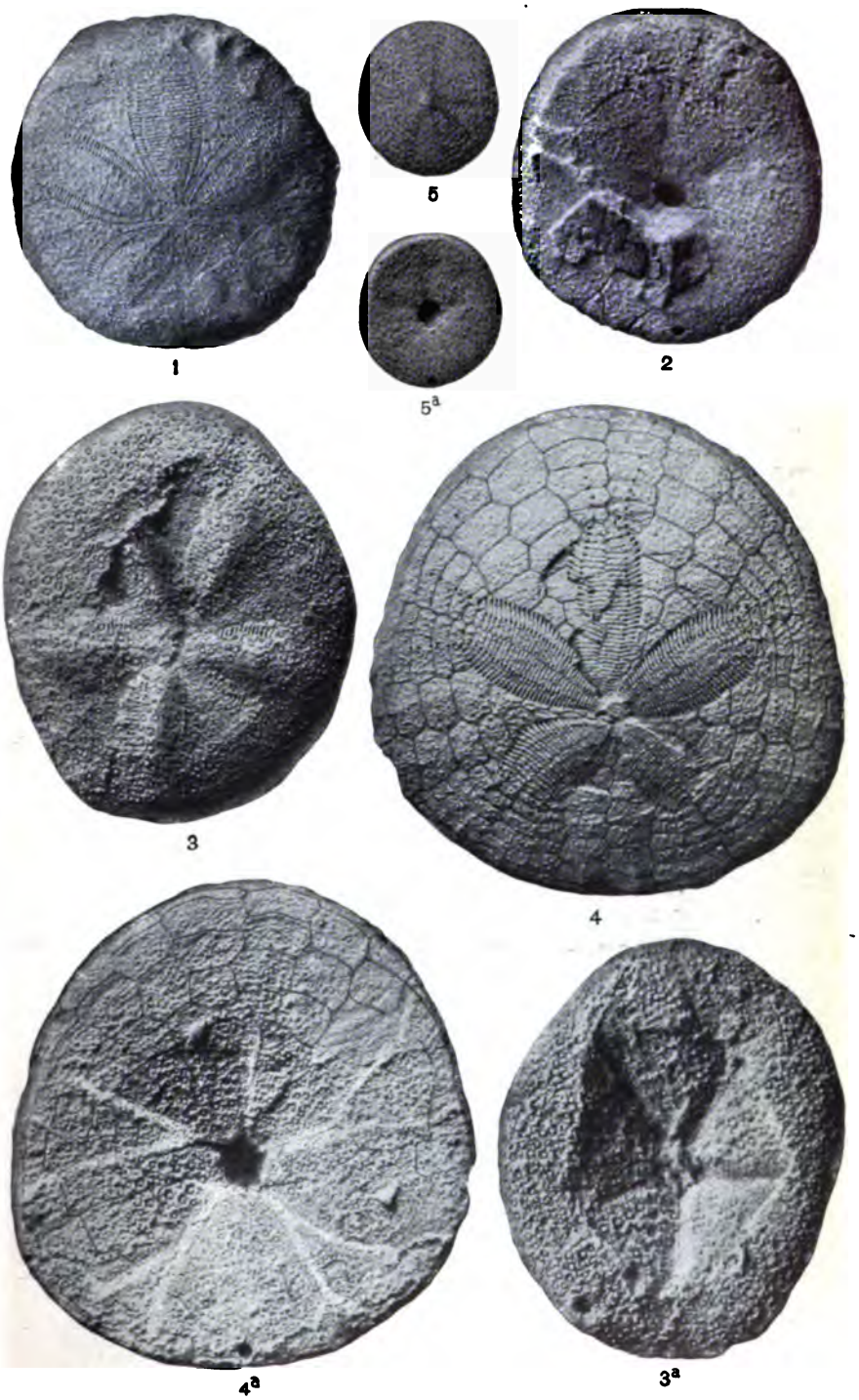

ETCHEGOIN ECHINODERMATA.

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PLATE LI.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: UPPERMOST FOSSIL BED.

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LITTORINA MARIANA var. ALTA Arnold.

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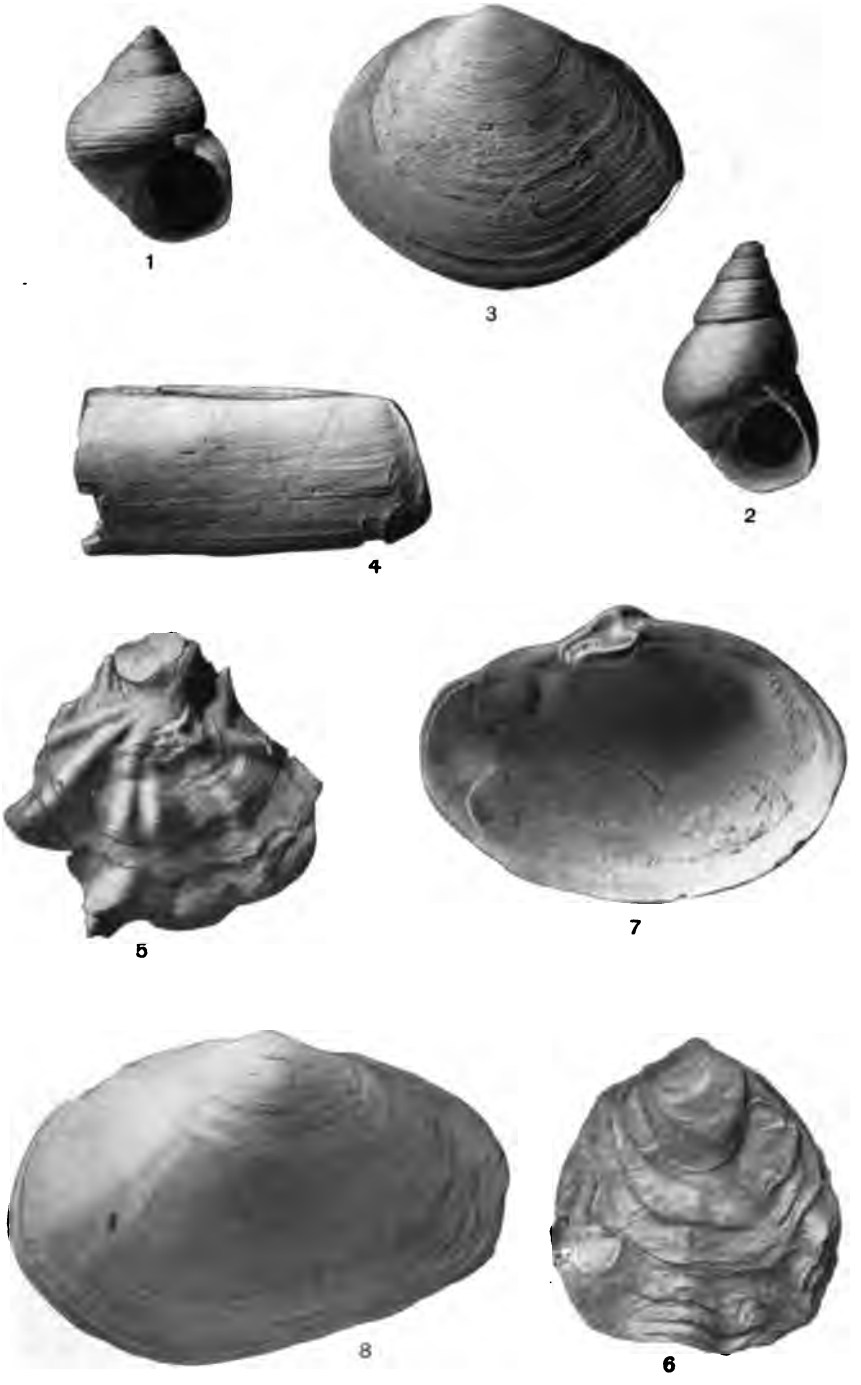

ETCHEGOIN FOSSILS.

PLATE LII.

PLATE LII.

TULARE FRESH AND BRACKISH WATER PLIOCENE) FOSSILS.

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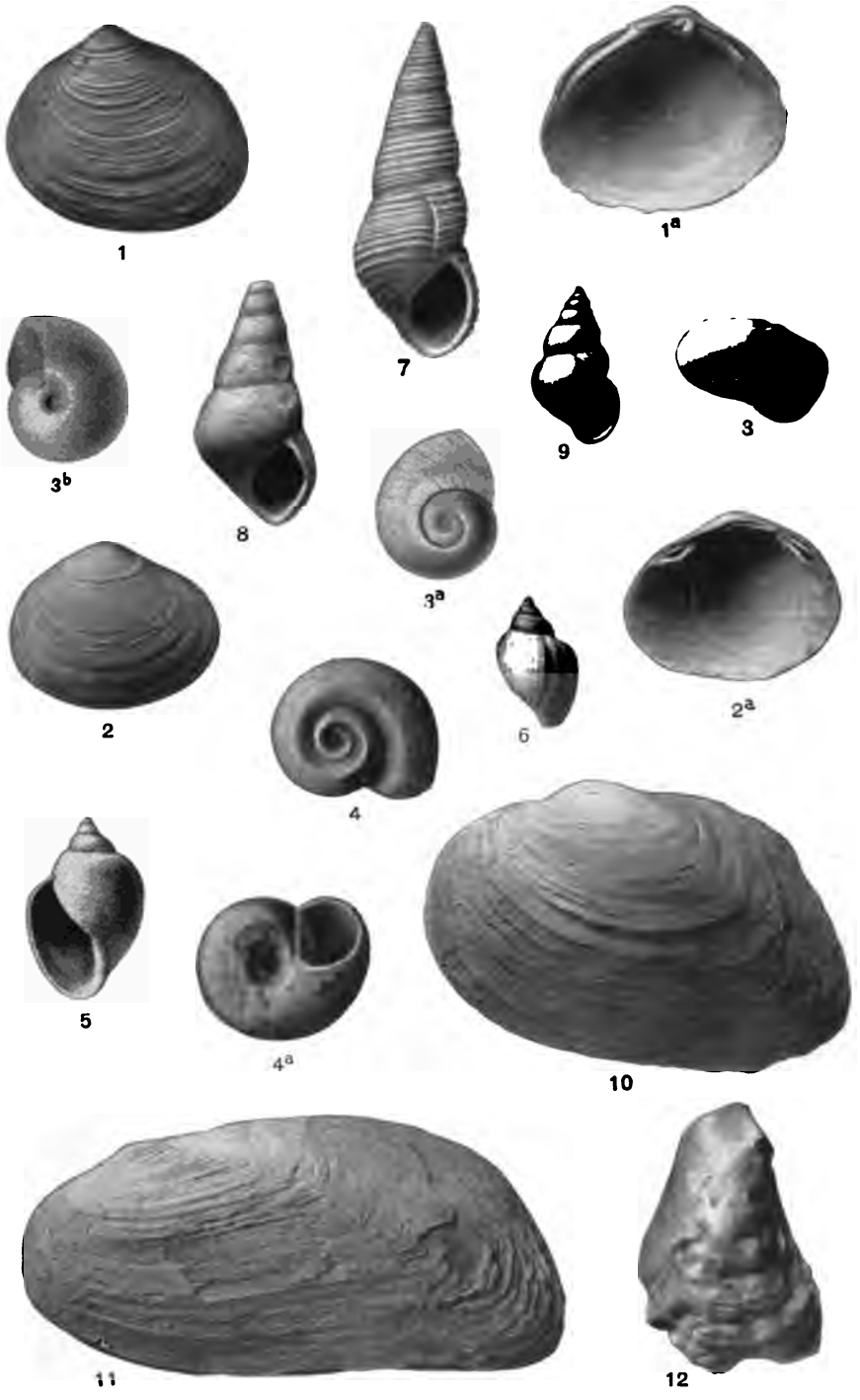

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THORNTON 15′ (ST. GEORGE 30′) QUADRANGLE.

GRAFTON, EAST ALONG HIGHWAY, VIA KNOTTSVILLE, SINCLAIR, AND FELLOWSVILLE, TO TUNNELTON.

	Feet.
Knottsville, 300 feet south of post-office, in large rock on east of road opposite house of W. E. Wilson; bronze tablet stamped "1484 ADJ 1903"	1,483.764
Claude, 1 mile northwest of, 3.1 miles southeast of Knottsville, 10 feet south of center of road, in large rock; bronze tablet stamped "1418 ADJ 1903"	1,418.038
Dent, opposite post-office, west side of road, 300 feet south of covered bridge over Sandy Creek, in large rock; bronze tablet stamped "1326 ADJ 1903"	1,325.749
Sinclair, 1 mile northeast of post-office, 250 feet north of forks, in large rock on east side of road; bronze tablet stamped "1489 ADJ 1903"	1,488.956
Sinclair, 3.4 miles north of post-office, 0.2 mile north of forks of road, 0.1 mile south of residence of H. Goff, west side of road, in large rock; bronze tablet stamped "1408 ADJ 1903." (The true elevation is possibly 1 foot greater)	1,408.185
Fellowsville, 0.3 mile northeast of, in bridge seat of south abutment of iron bridge over Little Sandy Creek; bronze tablet stamped "1379 ADJ 1903"	1,379.639
Fellowsville, 3.2 miles northeast of, 150 feet east of Bolyard residence, on right side of road, in large rock; aluminum tablet stamped "1625 ADJ 1903"	1,626.274

GRAFTON, EAST ALONG BALTIMORE AND OHIO RAILROAD, TO IRONTOWN; THENCE NORTH ALONG HIGHWAYS, VIA GLADESVILLE AND BROWNS MILL, TO MASONTOWN.[a]

Lesmalinston, in front of station; top of rail	1,031
Thornton, 0.1 mile west of, 5.7 miles east of Grafton; in bridge seat on east side of north abutment of iron bridge over Threefork Creek; aluminum tablet stamped "1041 ADJ 1903"	1,041.342
Irontown, 65 feet northwest of railroad, in large rock; bronze tablet stamped "1079 ADJ 1903"	1,079.002
Irontown, 2.5 miles northwest of, 175 feet east of house, forks of road to left in center of forks, in large rock; bronze tablet stamped "1506 ADJ 1903".	1,505.794
Irontown, 4.5 miles north of, 100 feet east of house, 150 feet west of road fork to north, north side of road, 15 feet from center, in rock; bronze tablet stamped "1431 ADJ 1903"	1,431.638
Gladesville, 75 feet south of post-office, at crossroads, in large rock; aluminum tablet stamped "1774 ADJ 1903"	1,773.901
Gladesville, 3.5 miles east of, at Browns Mills, at crossing of highway with Ices Ferry and Tunnelton pike, on Stony Run, south side of road, in large rock about 4 feet from bridge abutment; aluminum tablet stamped "1635 ADJ 1903"	1,635.701

BROWNS MILLS, SOUTHEAST ALONG TURNPIKE, TO TUNNELTON.

Oriole, in northwest corner of stone foundation of Pleasant Valley M. P. Church; bronze tablet stamped "1486 ADJ 1903." (This elevation is possibly 1 foot too great)	1,487.431

IRONTOWN, EAST ALONG BALTIMORE AND OHIO RAILROAD, TO TUNNELTON.

Hardman, 0.15 mile west of, 1.7 miles east of Irontown, bridge 97 over Raccoon Creek, near Taylor-Preston county line, in west abutment on north side; bronze tablet stamped "1111 ADJ 1903"	1,111.263
Newburg, 0.2 mile east of, on south side of Baltimore and Ohio Railroad, about 8 feet from track, in large rock; bronze tablet stamped "1232"	1,231.861

[a] An excessive error is distributed in this line.

TUNNELTON, NORTH ALONG HIGHWAY, TO HOWESVILLE.

	Feet.
Howesville, 700 feet south of post-office, on west side of West Virginia Northern Railroad, 940 feet west of George Rhodes's store; bronze tablet stamped "2222 ADJ 1903"	2,223.039

KINGWOOD 15′ (ST. GEORGE 30′) QUADRANGLE.

AT TUNNELTON.

Tunnelton, in southeast corner of large cut-stone building owned by J. J. Bonifield; bronze tablet stamped "1828 ADJ 1903"	1,829.682

HOWESVILLE, NORTHEAST ALONG HIGHWAY, TO ALBRIGHT.

Kingwood, at corner of Price and Main streets, on southwest corner, water table of Kingwood National Bank, east of front door; bronze tablet stamped "1862 ADJ 1903"	1,862.985
Albright, at northwest corner of iron bridge over Cheat River, in stone retaining wall; bronze tablet stamped "1217 ADJ 1903"	1,217.557

ALBRIGHT, SOUTHEAST ALONG HIGHWAYS, TO TERRA ALTA.

Albright, 2.6 miles southeast of, in front of residence owned by John Horner, in large rock on north side of road by water trough; bronze tablet stamped "1891 ADJ 1903"	1,891.249
Terra Alta, in foundation at southeast corner of large brick Offutt & Lakin Building; bronze tablet stamped "2559 ADJ 1903"	2,559.097

TERRA ALTA, SOUTH ALONG HIGHWAYS, VIA AURORA AND HORSESHOE RUN, TO SUMMIT OF MOUNTAIN NEAR PRESTON-TUCKER COUNTY LINE.[a]

Terra Alta, 4.2 miles south of, on farm of John Shaffer, in large rock on west side of road; bronze tablet stamped "2759 ADJ 1903"	2,759.272
Amboy, 1 mile north of, on farm owned by Robert McMickin, in large rock on west side of road; bronze tablet stamped "2700 ADJ 1903"	2,699.594
Aurora, in northeast corner of forks of road, in large rock; bronze tablet stamped "2640 ADJ 1903"	2,639.985
Aurora, 2.4 miles south of, in stone foundation of barn of Daniel J. King; bronze tablet stamped "2650 ADJ 1903"	2,650.479
Horseshoe Run, 1 mile southwest of post-office, in north side of stone foundation of church; bronze tablet stamped "2686 ADJ 1903"	2,685.737

ROWLESBURG, SOUTH ALONG HIGHWAYS, TO HANNAHSVILLE.

Rowlesburg, Baltimore and Ohio Railroad bench mark 75	1,401.265
Rowlesburg, in north side of west abutment of railroad bridge over Cheat River; bronze tablet stamped "1398 ADJ 1903"	1,398.387
Macomber, 3.1 miles south of Rowlesburg, 50 yards east of forks of roads with Northwestern turnpike, on south side of road by farm owned by Mrs. Macomber, in rock; bronze tablet stamped "1410 ADJ 1903"	1,410.152
Etam, 2.1 miles northwest of, on south side of road at forks leading to Dog Run, in large rock; bronze tablet stamped "1618 ADJ 1903"	1,618.211
Etam, southeast corner of stone foundation of schoolhouse; bronze tablet stamped "1765 ADJ 1905"	1,764.577

AT AMBLERSBURG.

Amblersburg, west end of south wall of railroad bridge over Saltlick Creek, opposite telegraph pole 250/27; bronze tablet stamped "1625 ADJ 1903" (set from corrected railroad precise levels)	1,625.349

[a] An excessive error is distributed in this line.

AT RODAMERS TUNNEL.

	Feet.
Rodamers, 0.25 mile northeast of station, south side of west portal of tunnel; bronze tablet stamped "2092 ADJ 1903" (set from corrected railroad precise levels)	2,092.350

PARSONS 15′ (ST. GEORGE 30′) QUADRANGLE.

MOUTH OF LICKING CREEK, ALONG HIGHWAYS UP CHEAT RIVER, TO PARSONS.

Hannahsville, 3.1 miles south of, west side of road at turn, in outcrop of rock; bronze tablet stamped "1659 ADJ 1903"	1,659.515
St. George, 1 mile north of, in south end of east abutment of iron bridge over Cheat River; bronze tablet stamped "1553 ADJ 1903"	1,553.064
St. George, 2.6 miles east of, iron bridge over Horseshoe Run, near mouth, in northwest wing wall of concrete abutment; aluminum tablet stamped "1576 ADJ 1903"	1,576.356
Parsons, 2 miles north of, iron highway bridge over Cheat River, in northwest bridge seat; bronze tablet stamped "1614 ADJ 1903"	1,614.140
Parsons, 900 feet east of, iron railroad bridge over Cheat River, in second step of southwest coping stone; bronze tablet stamped "1660 ADJ 1903"	1,649.837

UP HORSESHOE RUN, ALONG HIGHWAY TO TOP OF MOUNTAIN.[a]

Leadmine, 1 mile south of, in southeast bridge seat of iron highway bridge; aluminum tablet stamped "1727 ADJ 1903"	1,727.042
Leadmine, 2.4 miles northeast of, 970 feet north of intersection of road near mouth of Wolf Run, on west bank of Horseshoe Run, in ledge of rock; aluminum tablet stamped "1872 ADJ 1903"	1,872.311
Leadmine, 7 miles northeast of, on Hogback Mountain, in northwest corner of foundation of residence of David Ruth; aluminum tablet stamped "2482 ADJ 1903"	2,482.456

PARSONS, ALONG WESTERN MARYLAND RAILROAD, TO THOMAS.

Hambleton, road crossing at station; top of rail	1,682.7
Hendricks, wagon bridge spanning Black Fork of Cheat River, in northwest bridge seat; aluminum tablet stamped "1721 ADJ 1903"	1,721.004
Hendricks, 2.5 miles northeast of, in second step of northeast wing wall of iron railroad bridge; aluminum tablet stamped "1910 ADJ 1903"	1,910.117
Douglas (Albert), 1.1 miles southwest of, at milepost 81, in coping stone south side of east end of stone arch; aluminum tablet stamped "2631 ADJ 1903"	2,630.795
Douglas, in front of station; top of rail	2,796.1
Thomas, in southwest corner of Davis Coal and Coke Company's office; aluminum tablet stamped "2986 ADJ 1903"	2,986.462

HENDRICKS, SOUTHEAST ALONG DRY FORK RAILROAD, TO GLADWIN.

Hendricks, 3 miles southeast of, 900 feet north of milepost 3, 100 feet east of railroad, 70 feet southeast of spring under oak tree, near two large chestnut trees, in bowlder; aluminum tablet stamped "1788 ADJ 1903"	1,787.621
Hendricks, 6.4 miles southeast of, north of track, in side of cleft of rock; aluminum tablet stamped "1876 ADJ 1903"	1,876.266
Gladwin, at west side of north end of wooden railroad bridge spanning Dry Fork, in large sandstone ledge; aluminum tablet stamped "1944 ADJ 1903"	1,943.765

[a] An excessive error is distributed in this line.

PLATE LII.

PLATE LII.

TULARE (FRESH AND BRACKISH WATER PLIOCENE) FOSSILS.

SPHÆRIUM KETTLEMANENSIS Arnold.

Page.

Figure 1. Exterior of left valve; longitude 8 mm., × 4. Type, catalogue No. 165519. Tulare formation; locality 4731..... 153

1a. Interior of same specimen.

SPHÆRIUM COOPERI Arnold.

Figure 2. Exterior of right valve; longitude 9.5 mm., × 2. Type, catalogue No. 165528, U.S.N.M. Tulare formation; locality 4732..... 153

2a. Interior of same specimen.

CARINIFEX MARSHALLI Arnold.

Figure 3. Front, maximum diameter 3.7 mm., × 5. Type, catalogue No. 165507, U.S.N.M. Tulare formation; locality 4732..... 153

3a. Top of same specimen.

3b. Bottom of same specimen.

PLANORBIS VANVLECKI Arnold.

Figure 4. Top, maximum diameter 4.5 mm., × 5. Type, catalogue No. 165506, U.S.N.M. Tulare formation; locality 4731..... 153

4a. Bottom of same specimen.

PHYSA HUMEROSA Gould.

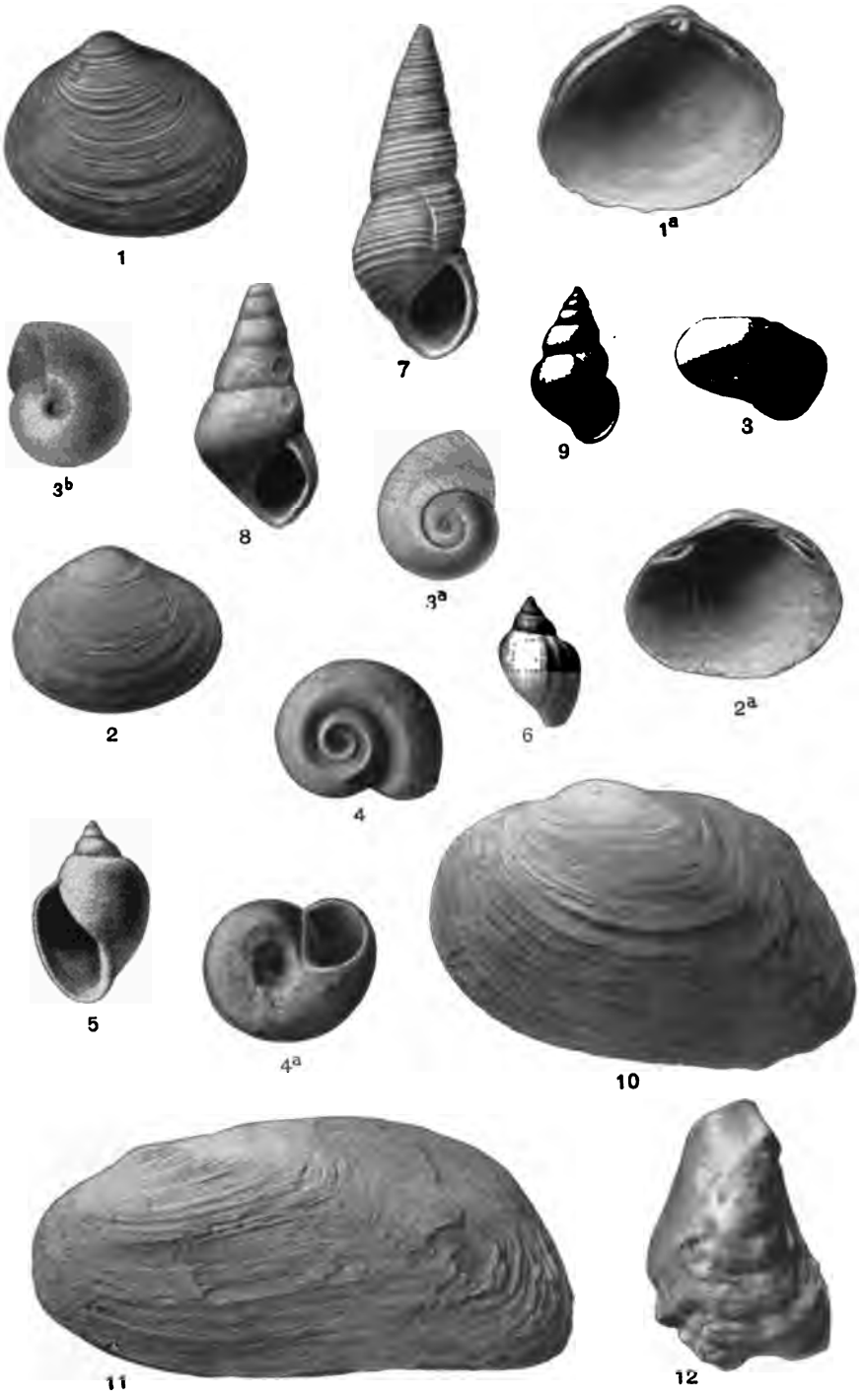
Figure 5. Front, longitude 8.5 mm., × 3. Catalogue No. 165502, U.S.N.M. Tulare formation; locality 4732. This species ranges from the Pliocene to the Recent fauna..... 153

PHYSA WATTSI Arnold.

Figure 6. Back, longitude 6 mm., × 3. Type, catalogue No. 165503, U.S.N.M. Tulare formation; locality 4732..... 153

GONIOBASIS KETTLEMANENSIS Arnold.

Figure 7. Front of a rather large specimen, altitude 22.5 mm., × 2. Type, catalogue No. 165501, U.S.N.M. Tulare formation; locality 4715. Also found in the Etchegoin formation..... 153



TULARE FOSSILS.

88170—Bull. 398—10——26

CLARKSBURG, WEST ALONG BALTIMORE AND OHIO RAILROAD, TO LYNCH.

	Feet.
Clarksburg, at corner of Pike and Third streets, in northwest corner of post-office, 2 feet above ground; aluminum tablet stamped "1006 GRAFTON".	1,007.699
Adamston, 0.5 mile west of, northeast corner of trestle 9, on top of stone; chiseled square	960.68
Wilsonburg, in front of station; top of rail	984
Wilsonburg, 0.5 mile west of, on small culvert south of track; chiseled square	997.66
Reynoldsville, at road crossing near station; top of rail	1,101
Wolf Summit, at southeast corner of William H. Dolan's store, in end of stone curbing; bronze tablet stamped "1133 GRAFTON 1901"	1,134.512
Lynch, 0.5 mile west of, trestle 14 of Baltimore and Ohio Railroad, on top of retaining wall on sixth stone from bridge; chiseled square	1,039.55

PHILIPPI QUADRANGLE.

BRIDGEPORT, VIA BERRYBURG, SWITZER, AND PLEASANT CREEK, TO WEBSTER.

Berryburg, Southern Coal and Transportation Company tipple, west of tipple and in front of power house, in fourth stone from top of retaining wall; bronze tablet stamped "1390 GRAFTON"	1,389.500
Switzer, 1.1 miles northeast of, east side of pike, on southeast corner of stone gate step of residence of B. H. Woodford; chiseled square	1,447.69
Pleasant Creek, brick residence of A. I. Cole, west corner of stone foundation, fifth stone from top and fourth from ground, 1.45 feet from corner; bronze tablet stamped "1170 GRAFTON"	1,170.044

SWITZER, SOUTH VIA PHILIPPI, TO PECKS RUN.

Switzer, 4 miles south of, covered bridge over Tygart River, in northwest corner of top stone of east abutment wall; chiseled square	1,308.01
Philippi, at north side of front entrance to brick schoolhouse, in center north face of foundation stone; bronze tablet stamped "1311 GRAFTON".	1,310.685
Buckhannon (Tygart) Junction, plate-girder bridge 1, over Tygart River, in north side of west abutment, in center of east face of first stone above bridge bed; bronze tablet stamped "1334 GRAFTON"	1,333.540
Volga (3.2 miles southwest of Malta), in north abutment of Baltimore and Ohio Railroad bridge over Wash Run, in east face in center of third stone from top; bronze tablet stamped "1404 GRAFTON"	1,403.859
Volga, 2.5 miles southwest of, on northwest corner of north abutment of bridge over Pecks Run, in second stone from top; chiseled square	1,405.46
Pecks Run (Hodgeville), in northwest corner of south abutment of bridge over Pecks Run, on west side of second stone from corner; chiseled square.	1,419.27

PECKS RUN, VIA PEELTREE AND OVERFIELD, TO PEPPER.

Peeltree, retaining wall in front of residence of Dr. Isaac Smith, at opening for steps, west face of south wall, in center of third stone above third step from sidewalk; bronze tablet stamped "1069 GRAFTON"	1,068.789
Peeltree, 2.9 miles north of, in front of Dever Picken's dwelling, in third step from bottom of stone stile; chiseled square	1,093.66
Peeltree, 4.4 miles north of, on southeast corner of north abutment of iron bridge over Elk Creek; chiseled square	1,023.10
Overfield, 3.1 miles northeast of, in front of Cletus Stout's dwelling, east side of stone stile, on north end of bottom step; chiseled square	1,103.11

PECKS RUN, SOUTH TO BUCKHANNON; THENCE NORTHWEST TO RURALDALE.

Ruraldale, 0.6 mile west of, near fork of road by old mill, 200 feet east of residence of V. H. Regar, in face of large rock; bronze tablet stamped "1121 GRAFTON 1901"	1,122.118

WESTON QUADRANGLE.

RURALDALE, NORTH VIA JOHNSTOWN, TO QUIET DELL; THENCE SOUTHWEST TO WEST MILFORD; THENCE NORTH TO CLARKSBURG.

	Feet.
Johnston, 0.1 mile west of, in face of ledge of rock north of road; bronze tablet stamped "1062 GRAFTON 1901"	1,062.946
Quiet Dell, 0.5 mile south of, 600 feet from crossroads, in large bowlder on west side of road; aluminum tablet stamped "1050 GRAFTON 1901"	1,050.778
West Milford, at southwest corner of highway bridge over West Fork River, in top of bridge seat; bronze tablet stamped "979 GRAFTON 1901"	979.365

WEST MILFORD, SOUTH ALONG HIGHWAYS, TO WESTON.[a]

Jane Lew, southeast end of railroad bridge over Hackers Creek, in top of first stone below bridge seat; aluminum tablet stamped "1007 GRAFTON 1901"	1,006.997

WESTON, ALONG ROAD, TO RURALDALE.

Weston, at end of southwest pier of Baltimore and Ohio Railroad bridge 24-A over West Fork River; bronze tablet stamped "1017 GRAFTON 1901"[b]	1,009.293

WESTON, SOUTH ALONG BALTIMORE AND OHIO RAILROAD, TO BROWNSVILLE.

Weston, 0.5 mile south of, on northeast corner of south abutment of railroad bridge 25 C; chiseled square	1,017.67
Brownsville, on northeast corner of west abutment of covered bridge; chiseled square	1,028.11

CENTERPOINT, LITTLETON, AND WEST UNION QUADRANGLES.

DODDRIDGE, HARRISON, MARSHALL, RITCHIE, TYLER, AND WETZEL COUNTIES.

Leveling in 1903 by George L. Gordon.

LITTLETON QUADRANGLE.

BELLTON, SOUTHWEST ALONG HIGHWAYS, VIA WEST, TO HALLS MILLS; THENCE SOUTH TO READER; THENCE EAST ALONG HIGHWAYS AND RAILROAD, TO JACKSONBURG; THENCE NORTHEAST ALONG HIGHWAY, TO LITTLETON.

	Feet.
Bannen, 1.1 miles of; schoolhouse subdistrict 9, 8.8 feet southwest of west corner; iron post stamped "1398 GRAFTON"	1,398.160
Bannen, 2.8 miles southwest of; schoolhouse at forks of road, stone steps, bottom step, west end; chiseled square	1,376.98
Silver Hill, bridge over Laurel Run, south end of west abutment; chiseled square	1,133.96
West, east angle of forks of road, outcrop of rock; bronze tablet stamped "1106 GRAFTON"	1,106.218
Bebee post-office, bottom step of stone stairway to house of Louis Feias; chiseled square	1,205.75
Halls Mills (5.3 miles southwest of West), north side of road near Thomas Adams's store and dwelling, outcrop of rock; bronze tablet stamped "774 GRAFTON"	774.396
Reader, county bridge over Fishing Creek, northeast corner of south abutment; aluminum tablet stamped "693 GRAFTON"	693.676

[a] The error distributed in this line is excessive.

[b] This description and corrected elevation were furnished by the chief engineer of the Baltimore and Ohio Railroad after reconstruction of pier.

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Venus varians Gabb..... 60
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Yoldia impressa Conrad..... 85, 86

Z.

Zirphæa dentata Gabb..... 85, 86, 94, 110, 111, *293*
gabbi Tryon..... 129, 132

THORNTON 15′ (ST. GEORGE 30′) QUADRANGLE.

GRAFTON, EAST ALONG HIGHWAY, VIA KNOTTSVILLE, SINCLAIR, AND FELLOWSVILLE, TO TUNNELTON.

	Feet.
Knottsville, 300 feet south of post-office, in large rock on east of road opposite house of W. E. Wilson; bronze tablet stamped "1484 ADJ 1903"	1,483.764
Claude, 1 mile northwest of, 3.1 miles southeast of Knottsville, 10 feet south of center of road, in large rock; bronze tablet stamped "1418 ADJ 1903"	1,418.038
Dent, opposite post-office, west side of road, 300 feet south of covered bridge over Sandy Creek, in large rock; bronze tablet stamped "1326 ADJ 1903"	1,325.749
Sinclair, 1 mile northeast of post-office, 250 feet north of forks, in large rock on east side of road; bronze tablet stamped "1489 ADJ 1903"	1,488.956
Sinclair, 3.4 miles north of post-office, 0.2 mile north of forks of road, 0.1 mile south of residence of H. Goff, west side of road, in large rock; bronze tablet stamped "1408 ADJ 1903." (The true elevation is possibly 1 foot greater)	1,408.185
Fellowsville, 0.3 mile northeast of, in bridge seat of south abutment of iron bridge over Little Sandy Creek; bronze tablet stamped "1379 ADJ 1903"	1,379.639
Fellowsville, 3.2 miles northeast of, 150 feet east of Bolyard residence, on right side of road, in large rock; aluminum tablet stamped "1625 ADJ 1903"	1,626.274

GRAFTON, EAST ALONG BALTIMORE AND OHIO RAILROAD, TO IRONTOWN; THENCE NORTH ALONG HIGHWAYS, VIA GLADESVILLE AND BROWNS MILL, TO MASONTOWN.[a]

Lesmalinston, in front of station; top of rail	1,031
Thornton, 0.1 mile west of, 5.7 miles east of Grafton, in bridge seat on east side of north abutment of iron bridge over Threefork Creek; aluminum tablet stamped "1041 ADJ 1903"	1,041.342
Irontown, 65 feet northwest of railroad, in large rock; bronze tablet stamped "1079 ADJ 1903"	1,079.002
Irontown, 2.5 miles northwest of, 175 feet east of house, forks of road to left in center of forks, in large rock; bronze tablet stamped "1506 ADJ 1903".	1,505.794
Irontown, 4.5 miles north of, 100 feet east of house, 150 feet west of road fork to north, north side of road, 15 feet from center, in rock; bronze tablet stamped "1431 ADJ 1903"	1,431.638
Gladesville, 75 feet south of post-office, at crossroads, in large rock; aluminum tablet stamped "1774 ADJ 1903"	1,773.901
Gladesville, 3.5 miles east of, at Browns Mills, at crossing of highway with Ices Ferry and Tunnelton pike, on Stony Run, south side of road, in large rock about 4 feet from bridge abutment; aluminum tablet stamped "1635 ADJ 1903"	1,635.701

BROWNS MILLS, SOUTHEAST ALONG TURNPIKE, TO TUNNELTON.

Oriole, in northwest corner of stone foundation of Pleasant Valley M. P. Church; bronze tablet stamped "1486 ADJ 1903." (This elevation is possibly 1 foot too great)	1,487.431

IRONTOWN, EAST ALONG BALTIMORE AND OHIO RAILROAD, TO TUNNELTON.

Hardman, 0.15 mile west of, 1.7 miles east of Irontown, bridge 97 over Raccoon Creek, near Taylor-Preston county line, in west abutment on north side; bronze tablet stamped "1111 ADJ 1903"	1,111.263
Newburg, 0.2 mile east of, on south side of Baltimore and Ohio Railroad, about 8 feet from track, in large rock; bronze tablet stamped "1232"	1,231.861

[a] An excessive error is distributed in this line.

	Feet.
West Union, 0.2 mile east of, in southwest corner of pier of Baltimore and Ohio Railroad bridge 23 over Middle Island creek; chiseled square, lettered "U. S. C. & G. S. N"	804.862
West Union, 1 mile east of; 60 feet west of junction of road, on southeast corner of east abutment to bridge over Rock Run; chiseled square	778.79

BLUE, ALONG HIGHWAY SOUTHWEST TO BEARSVILLE; THENCE SOUTH TO TOLLGATE.

Alma (Centerville), 3 miles south of, southwest angle of forks of road, under corner of store, on top of large flat rock; chiseled square	717.25
Alma, 6.5 miles southwest of (0.34 mile south of Bearsville) northeast of road, northwest side of hollow; in outcrop of rock; bronze tablet stamped "839 GRAFTON"	839.349
Molehill, north bank of Brush Run, at forks of road, in outcrop of rock; bronze tablet stamped "854 GRAFTON"	854.575
Molehill, 7.5 miles south of, on northeast bridge seat of iron bridge on old northwestern pike over North Fork of Hughes River; chiseled square	793.93
Tollgate post-office, 0.4 mile west of (about 10 miles west of West Union) on the southeast corner stone of pier of Baltimore and Ohio Railroad bridge 26; United States Coast and Geodetic Survey bench mark	802.817
Greenwood, 0.4 mile west of, north of Baltimore and Ohio Railroad, near center of rock cut; bronze tablet stamped "854 GRAFTON"	854.635

TOLLGATE, WEST ALONG BALTIMORE AND OHIO RAILROAD, TO ELLENBORO.

Pennsboro, railroad crossing; top of rail	861
Pennsboro, east face of Farmers and Merchants' Bank Building, 2.8 feet north of southwest corner, 2 feet above pavement; bronze tablet stamped "852 GRAFTON"	852.619
Ellenboro, 4.2 miles east of, about halfway between tunnels 8 and 9, on ledge of rock south of track; chiseled square	872.74

MIDDLEBOURNE, SOUTHWEST ALONG HIGHWAY, TO LITTLE POST-OFFICE.

Little post-office, on top of east pier south side of large iron bridge over Middle Island Creek; bronze tablet stamped "672 GRAFTON 1903"	672.187

HOLBROOK AND VADIS QUADRANGLES.

DODDRIDGE, GILMER, LEWIS, AND RITCHIE COUNTIES.

Leveling in Holbrook quadrangle in 1903 by G. L. Gordon and F. T. Willis and in Vadis quadrangle in 1902 by G. L. Gordon.

VADIS QUADRANGLE.

WEST UNION, SOUTHEAST ALONG PIKE, TO POINT 2.3 MILES SOUTHEAST OF NEW MILTON.

	Feet.
Sugarcamp, 0.5 mile southeast of, in southwest corner of east abutment of iron bridge over Meathouse Fork; bronze tablet stamped "830 GRAFTON" (mean of direct and reverse lines)	829.950

POINT 2.2 MILES SOUTHEAST OF NEW MILTON, SOUTHEAST ALONG PIKE, VIA AVON AND CHURCHVILLE, TO WESTON.

Avon, 0.2 mile south of, on west end of north abutment of covered bridge over Middle Island Creek; chiseled square	867.34
Churchville, 0.5 mile southeast of, left side of main road to Weston, in west side of middle of large rock; aluminum tablet stamped "972 GRAFTON"	971.906

WESTON, WEST ALONG ROAD, VIA ALUM BRIDGE AND LINN, TO MOUTH OF FINK CREEK; THENCE NORTH VIA HURST, TO NEW MILTON.

	Feet.
Camden, opposite post-office, in front yard to P. E. Fetty's house, 8.5 feet west of porch and 1 foot south of fence; iron post stamped "1096 GRAFTON"	1,095.782
Alum bridge, iron bridge over Alum Fork of Leading Creek, in southeast corner of west abutment; bronze tablet stamped "810 GRAFTON"	810.172
Linn, 1.75 miles northwest of, in northwest corner of bridge seat of east abutment of iron bridge over Fink Creek; bronze tablet stamped "766 GRAFTON"	766.091
Hurst, cliff facing south, 4.5 feet below top; bronze tablet stamped "815 GRAFTON"	814.958

AVON, EAST VIA COUNTY ROAD TOWARD BIG ISAAC.

Avon, 1.8 miles southeast of, in north angle of forks of road at Double Camp Run; iron post stamped "884 GRAFTON"	884.007

HOLBROOK QUADRANGLE.

WEST UNION, SOUTH ALONG HIGHWAY, VIA OXFORD, GROVE, AND TROY, TO LEADING CREEK.

West Union, 5.5 miles southwest of, large dwelling east side of road, near outcrop of rock; bronze tablet stamped "881 GRAFTON"	881.534
Oxford, 0.25 mile south of, in southeast corner of east pier of iron bridge over south fork of Hughes River; bronze tablet stamped "814 GRAFTON"	814.678
Grove, in northwest corner of cut-stone foundation of residence of C. A. Van Horn; bronze tablet stamped "918 GRAFTON"	917.908
Conings post-office, southeast corner of cut-stone foundation to store owned by H. W. Ryner; bronze tablet stamped "789 GRAFTON"	788.898
Troy, 0.25 mile west of, in northeast abutment of iron bridge over mouth of Cove Creek; bronze tablet stamped "758 GRAFTON"	759.114

GOOSENECK, SOUTH ALONG HIGHWAYS, TO HAZEL GREEN; THENCE SOUTHEAST, TO TROY.

Pullman, 0.2 mile west of, in outcrop of rock at northeast angle of crossroads; bronze table stamped "843 GRAFTON"	843.726
Slab, 0.3 mile northwest of post-office, left side of road, 100 feet north of small run, on top of outcrop of rock; chiseled square	791.825
Hazel Green, near northwest corner of store and post-office, in stone foundation; bronze tablet stamped "742 GRAFTON"	743.404
Lawford, in northeast corner of stone house of D. G. Law; bronze tablet stamped "820 GRAFTON"	820.694
Newberne, 0.5 mile above, in southeast corner of foundation to schoolhouse at forks of road; bronze tablet stamped "896 GRAFTON"	897.349
Coxs Mills (Troy dist. 6), northeast corner of stone foundation of schoolhouse; bronze tablet stamped "788 GRAFTON"	788.873

BURNSVILLE, GASSAWAY, GLENVILLE, AND SUTTON SPECIAL 15′ QUADRANGLES; BUCKHANNON AND SUTTON 30′ QUADRANGLES.

BRAXTON, CLAY, GILMER, LEWIS, NICHOLAS, UPSHUR, AND WEBSTER COUNTIES.

Leveling in Burnsville quadrangle in 1902 by G. L. Gordon; in Glenville quadrangle in 1903 by F. T. Willis and in 1905 by G. L. Gordon; in Buckhannon quadrangle in 1901–2 by G. L. Gordon; in Sutton Special quadrangle by G. L. Gordon and in 1908 by E. S. Dawson; and in Gassaway quadrangle in 1906 by D. D. Teets and in 1908 by E. S. Dawson.

BUCKHANNON 30′ QUADRANGLE.

BROWNSVILLE, SOUTH ALONG BALTIMORE AND OHIO RAILROAD, TO ARNOLD.

	Feet.
Rohrbough, in front of station; top of rail	1,036.5
Watson crossing; top of rail	1,049.0
Roanoke, 0.4 mile north of, on southeast corner of north abutment of iron bridge over Canos River; chiseled square	1,048.25
Roanoke, 1.8 miles southwest of, 0.6 mile northeast of Arnold, in southwest corner of southwest pier of railroad bridge No. 38–B over Monongahela River; bronze tablet stamped "1,058 GRAFTON"	1,057.970

AT BUCKHANNON.

Buckhannon, Upshur County court-house, west side of front entrance, in center of west face of base block of square column; aluminum tablet stamped "1433 GRAFTON"	1,432.881

BURNSVILLE 15′ (SUTTON 30′) QUADRANGLE.

ARNOLDSBURG, SOUTHWEST ALONG BALTIMORE AND OHIO RAILROAD, TO BURNSVILLE; THENCE NORTHWEST, ALONG HIGHWAY, TO LINN.

Confluence, 2.6 miles northeast of, 4.6 miles southwest of Arnold, on Second Big Run, on southwest corner of east abutment of railroad bridge 43–A; chiseled square	803.18
Confluence, 0.4 mile northeast of, opposite forks of county road, on north corner of pier of railroad bridge 46–A; chiseled square	777.26
Confluence, 0.8 mile southwest of, at forks of road, on northwest corner of west pier of railroad bridge 47–A; chiseled square	775.67
Burnsville, 0.5 mile north of, in top of east corner of northeast pier of railroad bridge 50–A over Little Kanawha River; bronze tablet stamped "765 GRAFTON"	764.616
Stouts Mills, iron bridge over Little Kanawha River, in northwest corner of east abutment; bronze tablet stamped "750 GRAFTON"	749.874

BURNSVILLE, SOUTHEAST ALONG ROAD, TO BULLTOWN; THENCE WEST, TO POINT 1 MILE NORTH OF ROLLYSON.

Bulltown, in north face of west abutment of covered bridge over Little Kanawha River, 9.8 feet below bridge seat and 8.1 feet west of corner; bronze tablet stamped "777 GRAFTON"	776.788

BURNSVILLE, SOUTH ALONG BALTIMORE AND OHIO RAILROAD AND HIGHWAYS, TO HEATERS.

Burnsville, 1.7 miles south of, on northwest corner of south abutment of railroad bridge 52–A over Saltlick Creek; chiseled square	765.14
Cogers, 3.4 miles south of, on northeast corner of south abutment of railroad bridge 55–D over Saltlick Creek; chiseled square	785.71
Rollyson, 0.5 mile north of, in bridge seat at northeast corner of south abutment of railroad bridge 57–D; bronze tablet stamped "797 GRAFTON"	796.934
Heaters, on southeast corner of west abutment of highway bridge over O'Brien Fork; chiseled square	865.22

GLENVILLE 15′ (SUTTON 30′) QUADRANGLE.

SAND FORK, WEST ALONG HIGHWAY, VIA GLENVILLE, TO DEKALB.

Glenville, 1.4 miles east of, on stone at southeast corner of iron bridge over mouth of Stewart Creek; chiseled square	721.61
Glenville, in top stone of middle pier on east side of bridge over Little [illegible]wha River; bronze tablet stamped "733 GRAFTON"	733.823

	Feet.
Glenville, 0.7 mile west of, on southeast corner of east abutment to bridge at mouth of Sycamore Run; square	716.02
Glenville, 3.7 miles west of, on northwest corner of west abutment to iron bridge across Leading Creek near mouth; square	723.66
Dekalb, 3.4 miles east of, on northwest corner of stone abutment to bridge across Sinking Creek; chiseled square	711.64
Dekalb, just back of post-office, in southwest corner of residence on second course of masonry foundation; bronze tablet stamped "715 GRAFTON"	715.895

GLENVILLE, SOUTHEAST ALONG HIGHWAY, TO CUTLIPS.

Glenville, 4.2 miles south of, on northwest abutment of iron bridge over Cedar Creek; square cut	740.38
Cedarville, 5.3 miles northwest of, on stone at ford over Cedar Creek; chiseled square	746.77
Cedarville, at front of residence of W. H. Jack, on west side of cut-stone steps, in big stone; aluminum tablet stamped "802 GRAFTON"	803.013
Cedarville, 6 miles southeast of, near house east of road, on big stone; chiseled square	822.99
Hope, about 2.5 miles east of, at forks of road leading up Toms Run, near hickory tree, on big rock; chisel mark	833.87
Cutlips, in southwest corner of cut-stone foundation of church; aluminum tablet stamped "851 GRAFTON" (elevation possibly 1 foot too high)	852.170

MOUTH OF TOMS RUN, WEST ALONG HIGHWAY, VIA HOPE, TO STUMPTOWN; THENCE NORTH, VIA NORMANTOWN, TO DEKALB.

Hope post-office, on stone foundation of old log stable; chiseled square	989.474
Hope, 1.4 miles southwest of, east of road fork at mouth of Leopard Run, in southwest corner of stone foundation to house occupied in 1903 by John Seal and owned by C. F. Gerwig; aluminum tablet stamped "861 GRAFTON"	861.863
Progress, 1 mile northwest of, near mouth of Piper Fork on Crooked Fork schoolhouse, at forks of road, on stone foundation at southwest corner; chiseled square	868.34
Perkins, to right of road at forks, on large stone; chiseled square	771.75
Perkins, 3.3 miles west of, in southwest corner of stone foundation of schoolhouse at forks of road; aluminum tablet stamped "741 GRAFTON"	742.243
Stumptown, 0.5 mile east of, at forks of road, in southeast corner of east pier of iron bridge over Left Fork of Steer Run; bronze tablet stamped "714 GRAFTON"	714.952
Normantown, on stone at forks of road up Steer Run; chiseled square	737.45
Lettergap, at south angle of crossroads, in northwest face of foundation stone at north corner of dwelling of A. S. Westfall; aluminum tablet stamped "827 GRAFTON"	828.049

SUTTON SPECIAL (SUTTON 30′) QUADRANGLE.

HEATERS, SOUTH ALONG BALTIMORE AND OHIO RAILROAD, TO SUTTON; THENCE ALONG HIGHWAY AND ACROSS COUNTRY, TO BIRCH RIVER.

Shaversville (Flatwoods post-office), Dr. B. M. Squire's drug store, 0.8 foot west and 3.5 feet south of northwest corner; iron post stamped "1071 GRAFTON"	1,070.810
Flatwoods, 1.6 miles south of, northeast corner of south abutment of railroad bridge 64–B; chiseled square	1,051.89
Sutton, 2.3 miles north of (3.7 miles south of Flatwoods), on northeast corner of south abutment of railroad bridge 66–D; chiseled square	863.15

	Feet.
Station at suspension bridge over Elk River, in north face of north tower, 0.9 foot above foundation and 2.4 feet east of corner; bronze tablet stamped "843 GRAFTON"	842.477
Littleton, 2 miles west of, 160 feet northwest of Bear Run, 50 feet northwest of road forks, north of road, in outcrop of rock; bronze tablet stamped "1073 GRAFTON"	1,072.575
Birch River, 300 feet north of post-office, 0.2 mile south of mouth of Powell Creek, on east side, opposite Ivan Brothers and Brown's store, in outcrop of rock; aluminum tablet stamped "1108 KNWA" (21st Annual Report elevation retained)	1,108.365

BIRCH RIVER, EASTWARD ALONG HIGHWAY, TO ERBACON; THENCE NORTH, ALONG BALTIMORE AND OHIO RAILROAD, TO GILLESPIE.

Birch River post-office, 3 miles east of, 150 feet west of Birch Valley schoolhouse No. 24, 170 feet east of ford, north of river and road, in east end of large rock bowlder; aluminum tablet stamped "1186"	1,186.091
Waggy post-office, 0.5 mile west of, south of ridge road, 300 feet west of Tram road and water tank, 0.3 mile east of road forks, in rock bowlder; aluminum tablet stamped "2085"	2,084.528
Waggy post-office, 1 mile east of, north of county road, south of Tram road, near summit, 0.4 mile from where Tram road leaves ridge road, in outcrop of rock; aluminum tablet stamped "2176"	2,175.859
Erbacon, 100 feet east of post-office, 100 feet south of station, in abutment at northwest end of Baltimore and Ohio bridge over mouth of Missouri Creek; aluminum tablet stamped "1518"	1,517.654
Defoe, in front of station; top of rail	1,401
Erbacon, 2.7 miles north of, east of railroad, 0.1 mile north of Defoe station, 150 feet south of milepost 81, in top of stone culvert; aluminum tablet stamped "1373"	1,372.951
Erbacon, 3.7 miles north of, west of railroad, east of Laurel Creek, 150 feet south of milepost 80, on outcrop of sand rock; chiseled square; marked "1286"	1,285.77
Erbacon, 4.7 miles north of, west of railroad, 200 feet south of milepost 79, on sand rock, chiseled square; marked "1203"	1,202.83
Prestonia post-office, 0.1 mile north of, near mouth of Brook Run, in top stone of abutment to railroad bridge over Laurel Creek; aluminum tablet stamped "1137"	1,136.921
Custis, in front of station; top of rail	1,073. (?)
Centralia, 400 feet south of post-office, opposite G. E. & H. A. Hyer's store, 40 feet south of road crossing, 400 feet south of station, 20 feet east of railroad, 0.1 mile south of mouth of Laurel Creek, in stone culvert; aluminum tablet stamped "945"	944.619
Centralia, 1.1 miles north of, east of railroad, west of Elk River, opposite rock cliff, 200 feet south of milepost 48, on outcrop of sand rock, chiseled square; marked "952"	951.51
Bakers Run, 1 mile north of, west of railroad, 150 feet south of house, opposite mouth of Holly River, in outcrop of sand rock in bank; aluminum tablet stamped "943"	942.486
Bakers Run, 2 miles north of, south of railroad and river, 1 mile east of Holly River Junction, on outcrop of sand rock, chiseled square; marked "914".	913.10
Gillespie station, 0.5 mile south of, 40 feet south of milepost "C–69 & R–53," east of railroad, west of county road, 430 feet north of road crossing, in east end of culvert; aluminum tablet stamped "890"	889.665
Gillespie, in front of station; top of rail	890.

	Feet.
Gillespie, 0.5 mile north of, on edge of county road near summit, on outcrop of sand rock, chiseled square; marked "930"	929.79
Gillespie, 1.2 miles northwest of, west of trail, opposite field, 0.2 mile south of house, on outcrop of rock, chiseled square; marked "886"	885.20
Gillespie, 2.2 miles northwest of, west of trail, on top of summit 0.5 mile west of house, in rock cliff; aluminum tablet stamped "945"	944.275

GASSAWAY 15′ (SUTTON 30′) QUADRANGLE.

NEAR SUTTON, WEST ALONG HIGHWAY, TO GASSAWAY; THENCE SOUTHWEST ALONG COAL AND COKE RAILROAD, TO OTTER.

Sutton, 3 miles west of, 0.2 mile west of Buffalo Ford, 800 feet east of old sawmill, in abutment of small bridge over Mud Run; aluminum tablet stamped "822"	821.723
Gassaway, 0.5 mile east of, in second stone of abutment at northeast end of railroad bridge over Elk River; aluminum tablet stamped "839"	838.819
Gassaway, in front of station; top of south rail	833.6
Gassaway, 0.5 mile west of, south of railroad, at end of yard limit, on sandstone in culvert over run, chiseled square; marked "831"	831.03
Gassaway, 1.5 miles west of, south of railroad and Elk River, on doorstep of house, chiseled square; marked "833"	832.53
Gassaway, 2.6 miles west of, south of railroad and Elk River, 0.3 mile south of sawmill, in outcrop of sand rock; aluminum tablet stamped "831"	831.019
Gassaway, 3.6 miles west of, south of railroad and Elk River, 70 feet east of hollow, on outcrop of sand rock, chiseled square; marked "829"	828.47
Gassaway, 4.6 miles west of, south of railroad and Elk River, 0.1 mile west of road crossing, on rock cliff, chiseled square; marked "825"	824.37
Gassaway, 5.6 miles west of, west of railroad and Elk River, 200 feet from mouth of Lower Rockcamp Run, opposite sawmill, in outcrop of rock; aluminum tablet stamped "825"	825.028
Gassaway, 6.6 miles west of, north of railroad and south of Elk River, on outcrop of sand rock, chiseled square; marked "823"	822.19
Frametown, 200 feet south of post-office, in southeast abutment of county iron bridge over Elk River; aluminum tablet stamped "817"	816.426
Frametown, 1 mile west of post-office, 0.2 mile north of Rockton station, east of railroad and Elk River, on rock cliff, chiseled square; marked "817"	816.99
Rockton, 1.9 miles south of, southeast of railroad and river, in outcrop of sand rock; aluminum tablet stamped "813"	812.466
Glendon, 0.5 mile south of post-office, on southwest abutment of railroad bridge over Birch River, chiseled square; marked "811"	810.20
Glendon, 1.9 miles south of, southeast of railroad, near bend, on outcrop of sand rock, chiseled square; marked "806"	805.95
Strange Creek post-office, 200 feet north of station, in northeast abutment of railroad bridge over mouth of Strange Creek; aluminum tablet stamped "807"	806.515
Strange Creek post-office, 1 mile west of, north of railroad, near bend south of river, on outcrop of sand rock, chiseled square; marked "807"	806.99
Villa Nova, 140 feet north of store and station, opposite house, west of railroad, east of river, in southwest corner of culvert; aluminum tablet stamped "787"	786.981
Villa Nova, 1.6 miles southwest of, south of railroad, 250 feet east of Frame Run, on rock cliff, chiseled square; marked "795"	794.24

	Feet.
Ira, 0.5 mile west of post-office, 250 feet south of station, in northeast abutment of railroad bridge over mouth of Grove Run; aluminum tablet stamped "788"	787.822
Ira, 1 mile southwest of, west of railroad, east of river, 300 feet north of sawmill and hollow to west, on rock bowlder, chiseled square; marked "784"	784.10
Ira, 2.1 miles southwest of, on southeast abutment of bridge over Jumping Gut, chiseled square; marked "780"	779.81
Ira, 3.1 miles southwest of, in top of stone in south end of culvert; aluminum tablet stamped "772"	771.579

STRANGE CREEK, SOUTHEAST TO BIRCH RIVER POST-OFFICE.

Strange Creek post-office, 1 mile southeast of, 50 feet east of road crossing, 300 feet east of Upper Mill Creek, 100 feet east of road forks, on outcrop of sand rock, chiseled square; marked "818"	818.16
Strange Creek, 2 miles southeast of, south of road in bank, 180 feet west of road crossing, opposite house and hollow, in outcrop of sand rock; aluminum tablet stamped "879"	878.731
Jennings, 0.5 mile east of post-office, west of railroad, on edge of creek, at west end of trestle, on rock, chiseled square; marked "898"	897.50
Jennings, 2.4 miles southeast of, east of railroad, north of Strange Creek, 70 feet south of house, opposite hollow between trestles, in outcrop of sand rock; aluminum tablet stamped "993"	993.092
Jennings, 3.6 miles southeast of, 100 feet north of Trace Fork at mouth, east of railroad and creek, on sand rock, chiseled square; marked "1044"	1,043.96
Jennings, 4.6 miles southeast of, east of road, 300 feet south of road to west, on sand rock, chiseled square; marked "1223"	1,222.60
Jennings, 5.5 miles southeast of, between Ball schoolhouse and New Hope Church, 10 feet south of road fork, 300 feet west of Morris's store, in hollow between Hughes Mountain and Kenna Mountain, in outcrop of sand rock; aluminum tablet stamped "1253"	1,252.773
Jennings, 7.6 miles southeast of, 0.5 mile east of Big Birch Ford, opposite hollow to right, north of river, on outcrop of sand rock, chiseled square; marked "1106"	1,105.17

IVYDALE, SOUTHEAST TO BUFFALO CREEK.

Ivydale, 3.2 miles southeast of, on ridge from Ivydale to Buffalo Creek, northeast of road, in large stone; aluminum tablet stamped "1308" (this elevation may be a foot too great)	1,307.847

FRAMETOWN, NORTHWEST TO MOUTH OF JOES FORK OF STEER CREEK.[a]

Frametown, 0.5 mile north of post-office, southwest of road, on edge of bank, 0.5 mile north of mouth of Big Run, 100 feet west of Big Run schoolhouse, on sand rock, chiseled square; marked "827"	827.05
Frametown, 3.3 miles northwest of, south of run, north of road, 100 feet east of private road to north, 300 feet west of old store, on small rock, chiseled square; marked "977"	976.87
Dessie, 0.5 mile northeast of post-office, 130 feet northwest of road forks, 200 feet east of Joes Fork at mouth, 10 feet west of foot log, opposite hollow, in outcrop of sandstone; aluminum tablet stamped "908"	907.898

[a] Mean of two runnings.

ELIZABETH AND HARRISVILLE QUADRANGLES.

RITCHIE, WIRT, AND WOOD COUNTIES.

Leveling in Elizabeth quadrangle in 1904 by G. L. Gordon, and in Harrisville quadrangle in 1903 by G. L. Gordon and R. E. McFadden, and in 1904 by George Seidel.

ELIZABETH QUADRANGLE.

DAVISVILLE, EAST ALONG BALTIMORE AND OHIO RAILROAD, TO PETROLEUM.

	Feet.
Davisville, at railroad crossing; top of rail	610
Davisville, at center of west end of railroad culvert; aluminum tablet stamped "601 ADJ 1903"	601.428
Davisville, 1.7 miles east of, in top of southeast abutment at southwest end of railroad bridge 51 over Stillwell Creek; chiseled square	607.53
Kanawha Station, at crossing; top of rail	611.5
Kanawha, 0.9 mile southeast of station, northwest end of railroad tunnel, southwest side of track, fifth stone from bottom next opening; aluminum tablet stamped "615 ADJ 1903"	615.096
Kanawha, 2 miles southeast of station, on top of southwest end of southeast abutment of railroad bridge 50; chiseled square	608.68
Hanna, road crossing; top of rail	623.3
Hanna, 0.14 mile east of post-office, in bridge seat at southwest end of west abutment of railroad bridge 48 over Walker Creek; bronze tablet stamped "623 ADJ 1903"	623.503
Walker, in front of station; top of rail	629.4
Walker, 2.4 miles east of, in southeast corner of east abutment of railroad bridge 46 over Walker Creek; aluminum tablet stamped "698 ADJ 1903".	698.105
Eaton, in front of station; top of rail	775.3
Eaton, 0.5 mile east of, north side of track, in face of rock cliff; aluminum tablet stamped "752 ADJ 1903"	752.123
Petroleum, 1 mile west of, on northeast corner stone of railroad bridge 44; chiseled square	693.171
Petroleum, at road crossing; top of rail	695.8
Petroleum, near, on south end of west abutment of railroad bridge 41; chiseled square	698.03
Petroleum, 0.4 mile east of, in top of south side of west abutment to railroad bridge 40; bronze tablet stamped "700 ADJ 1903"	700.320

PETROLEUM, SOUTH ALONG HIGHWAY, TO CISKO; THENCE SOUTHWEST TO ELIZABETH.

Petroleum, 2.8 miles south of, 100 feet southeast of summit, northeast side of road, in rocky ledge; aluminum tablet stamped "1084 ADJ 1903"	1,084.158
Cisko, 46 feet southwest of southwest corner of Buffalo M. P. Church; iron post stamped "640 ADJ 1903"	640.425
Cisko, 3.6 miles southwest of, 90 feet east of northeast corner of schoolhouse, in west face of large rock; bronze tablet stamped "702 ADJ 1903"	702.129
Standingstone, 3.5 miles east of, 540 feet southwest of Parish Fork schoolhouse, left side of road, in top of large rock; bronze tablet stamped "736 ADJ 1903"	735.694
Standingstone, 0.8 mile southeast of, 840 feet east of forks of road; on right side of road, in top of large rock; bronze tablet stamped "619 ADJ 1903".	619.083

KANAWHA, SOUTH ALONG LITTLE KANAWHA RAILROAD, TO PALESTINE.

	Feet.
Leachtown, at road crossing; top of rail	617.4
Leachtown, west side of railroad, in rock cliff; bronze tablet stamped "620 ADJ 1903"	620.204
Slate, at road crossing; top of rail	608.5
Fishing Camp, in front of station; top of rail	614.7
Hughes River station, 2.5 miles east of Slate, 15 feet northeast of northeast corner of station; iron post stamped "618 ADJ 1903"	617.812
Newark, in front of station; top of rail	614.1
Newark, 1.4 miles southeast of, 24 feet west of track; iron post stamped "627 ADJ 1903"	627.209
Standingstone, at road crossing; top of rail	621.0
Elizabeth, on southwest curb line of Washington street, point southeast of north corner of Raleigh Hotel, south meridian mark, in stone post; bronze tablet stamped "646 ADJ 1903"	646.037
Palestine (Reedyripple), 150 feet east of post-office, 18 feet south of railroad; iron post stamped "645 ADJ 1903"	644.657

PALESTINE, SOUTH ALONG HIGHWAY, TO ROVER.

Rover, 0.8 mile southwest of, 250 feet southeast of stillhouse, left side of road at southeast end of large high rock in top of large low rock; aluminum tablet stamped "627 ADJ 1903"	626.560

ELIZABETH, SOUTHEAST ALONG HIGHWAY, TO BURNING SPRINGS.

Elizabeth, 2.75 miles southeast of, 350 feet southwest of a small run, east side of road, in large rock 9 feet above road; aluminum tablet stamped "700 ADJ 1903"	700.088
Cherry, 0.3 mile north of, Highlog Run, in northeast corner of south abutment of iron bridge; bronze tablet stamped "633 ADJ 1903"	633.424

CISKO, SOUTHEAST ALONG HIGHWAY, TO OXBOW.

Cisko, 2.73 miles southeast of, in northeast corner of southeast abutment of county bridge over Camp Run; aluminum tablet stamped "637 ADJ 1903"	637.245

HARRISVILLE QUADRANGLE.

OXBOW, SOUTH ALONG HIGHWAY, VIA MACFARLAN, TO MUNDAY.

Oxbow, 0.7 mile northwest of, 200 feet northeast of road crossing of Louthers Run and close to a small stream, right side of road, in shelf of outcrop of rock; bronze tablet stamped "659 ADJ 1903"	659.136
Macfarlan, 150 feet southwest of post-office and station, left side of road, in top of large rock; bronze tablet stamped "668 ADJ 1903"	668.015
Macfarlan, road crossing; top of rail	658.8
Macfarlan, 3 miles southeast of, 155 feet north of hollow, in shelf of outcrop of rock; bronze tablet stamped "757 ADJ 1903"	757.318
Hartley, 0.1 mile south of, at forks of road near a church and a store, in northeast angle, in top of outcrop of rock; aluminum tablet stamped "931 ADJ 1903"	931.272
Hartley, 2.85 miles southwest of, 0.13 mile north of Munday, west side of road, in outcrop of rock 5 feet above road; bronze tablet stamped "742 ADJ 1903"	742.144

NOBE, NORTHWEST ALONG LEATHERBARK RUN ROAD, TO SMITHVILLE; THENCE EAST TO HAZEL GREEN.

Smithville, in southwest corner of stone foundation of house owned by M. A. Ayers; bronze tablet stamped "718 GRAFTON"	719.251

PENNSBORO, SOUTHWEST ALONG PENNSBORO AND HARRISVILLE RAILROAD, TO GOOSENECK.

	Feet.
Gooseneck, at road crossing; top of rail	741.2
Gooseneck, 0.1 mile southwest of, at south end of foot bridge over North Fork, Hughes River, in rock cliff; bronze tablet stamped "732 GRAFTON"	732.860

ELLENBORO, SOUTHWEST ALONG BALTIMORE AND OHIO RAILROAD, TO CAIRO; THENCE NORTHWEST ALONG HIGHWAY, TO NUTTER FARM; THENCE SOUTHEAST TO PETROLEUM.

Cornwallis, 2.8 miles northeast of, on coping stone of southwest abutment of Baltimore and Ohio Railroad bridge 30; chiseled square	739.342
Cornwallis, 1.8 miles northeast of, at west end of Baltimore and Ohio Railroad tunnel 11, south side of track, on corner of foundation stone; chiseled square	709.21
Cornwallis, in front of station; top of rail	686.7
Cornwallis, 375 feet west of, in bridge seat at north end of east abutment of bridge 32; bronze tablet stamped "681 GRAFTON 1903"	681.438
Cairo, 1 mile east of, on south end of east abutment of railway bridge 35 over Bonds Creek; Coast and Geodetic Survey bench mark XXXVI	685.954
Cairo, in front of freight station; top of low rail	680
Cairo, in railway bridge 36, in north end of east abutment; bronze tablet stamped "674 GRAFTON 1903"	674
Nutter farm, a short distance north of A. B. Wilson's store, in bridge seat at north end of west abutment of new county bridge over Goose Creek; bronze tablet stamped "733 GRAFTON 1903"	733.189
Petroleum, 3.7 miles northeast of, north side of road, opposite farmhouse of W. H. Cantwell, in ledge of rock between road and creek; bronze tablet stamped "714 ADJ 1903"	713.442

CAIRO, SOUTHWEST ALONG HIGHWAY, TO CISKO.

Cairo, 3.9 miles south of, at pumping station, 200 feet south of west end of footbridge, in large rock; aluminum tablet stamped "657 ADJ 1903"	657.200
Rusk, 3.9 miles northwest of, east side of road, between road and small run, 500 feet north of A. R. Phillips's house, in ledge of rocks; bronze tablet stamped "671 ADJ 1903"	670.608

CORNWALLIS, SOUTHEAST ALONG HIGHWAY, TO GOFFS; THENCE SOUTHWEST TO SMITHVILLE.

Harrisville, in west end of doorstep of main entrance of court-house; aluminum tablet stamped "871 ADJ 1903"	870.568
Washburn, 0.5 mile northeast of new post-office, southwest corner of store owned and occupied by D. S. Hall & Bros.; bronze tablet stamped "756 ADJ 1903"	756.087
Goffs post-office, west end of north abutment of big iron bridge across South Fork, Hughes River; aluminum tablet stamped "714 ADJ 1903"	713.883

ARNOLDSBURG, RIPLEY, AND SPENCER QUADRANGLES.

CALHOUN, JACKSON, ROANE, AND WIRT COUNTIES.

Leveling in Arnoldsburg quadrangle in 1903 and 1904 by F. T. Willis, and in 1905 by D. D. Teets; in Ripley quadrangle in 1905 by G. L. Gordon; and in Spencer quadrangle in 1904 and 1905 by G. L. Gordon, and in 1905 by D. D. Teets.

ARNOLDSBURG QUADRANGLE.

CRESTON, EAST ALONG HIGHWAY VIA GRANTSVILLE, TO WHITE PINE.

	Feet.
Annamoriah, 0.2 mile north of, in southwest angle of forks of road near spring, in east end of outcrop of rock; bronze tablet stamped "945 ADJ 1903"	945.053
Big Bend (Brooksville), 0.46 mile west of, right side of road, in northwest face of large rock; bronze tablet stamped "673 ADJ 1903"	672.920
Purdy, on west side of county road about 105 feet northeast of post-office, in southeast face of large rock; bronze tablet stamped "706 ADJ 1903"	705.790
Grantsville, in northwest corner of west face of stone foundation of courthouse; bronze tablet stamped "725 GRAFTON"	726.451
Whitepine, 4.9 miles northeast of Grantsville, 600 feet west of forks of road and 12 feet south of road crossing of small run, in northwest corner of large rock; bronze tablet stamped "787 ADJ 1903"	786.710

STUMPTOWN, WEST ALONG HIGHWAY VIA ARNOLDSBURG, TO PINK; THENCE NORTH TO CRESTON.

Stumptown, 2.1 miles southwest of, north side of road, 220 feet southeast of a hollow, in south face of large rock; aluminum tablet stamped "752 ADJ 1903"	753.296
Millstone, 0.5 mile northeast of, in center of corner stone of Sand Ridge Church; bronze tablet stamped "1203 ADJ 1903"	1,204.005
Arnoldsburg, 0.4 mile east of, 125 feet southwest of hollow near junction of road from south, north side of road, in face of outcrop of rock; bronze tablet stamped "733 ADJ 1903"	734.389
Beech, 0.24 mile northeast of post-office, 90 feet southwest of mouth of hollow from southeast side of road, in top of large rock; bronze tablet stamped "742 ADJ 1903"	743.356
Pink, 0.87 mile east of, west side of road, in top of large rock; bronze tablet stamped "709 ADJ 1903"	710.415
Tristan, 0.5 mile north of, west side of road, near a poor dwelling, in large rock; bronze tablet stamped "709 ADJ 1903"	710.462
Rocksdale, 0.08 mile west of, north side of West Fork Little Kanawha River, opposite mouth of Henry Fork, north side of road, in southeast end of large rock; bronze tablet stamped "679 ADJ 1903"	680.554
Richardson, 5 feet northeast of northeast corner of W. E. Bee's store; iron post stamped "674 ADJ 1903"	675.982

BIG BEND, NORTH ALONG HIGHWAY, VIA INDUSTRY, TO MUNDAY.

Industry, 1.9 miles west of, 125 feet northwest of ford, on north side of Straight Creek, in face of outcrop of rock; bronze tablet stamped "663 ADJ 1903"	663.049

GRANTSVILLE, NORTHEAST ALONG HIGHWAY, TO NOBE.

Nobe, at northwest corner of Chapel Church, in north foundation wall; bronze tablet stamped "1090 GRAFTON"	1,091.379

GRANTSVILLE, SOUTH ALONG HIGHWAY, TO ARNOLDSBURG.

Sycamore, 3.34 miles north of, on dividing ridge between Philip Run and Sycamore Creek; in center of corner stone of schoolhouse 150 feet east of road; bronze tablet stamped "1009 ADJ 1903"	1,009.425
Sycamore, 0.2 mile south of, on Sycamore Creek, on east side of road, opposite house to west of road, in stone; bronze tablet stamped "814 ADJ 1903"	814.211

RIPLEY QUADRANGLE.

RAVENSWOOD, EAST ALONG BALTIMORE AND OHIO RAILROAD, TO DUKES (DOUBLE-RODDED LINE).

	Feet.
Silverton, 0.5 mile west of (2.5 miles east of Ravenswood), north side of track, in ledge of rock; bronze tablet stamped "579 ADJ 1903"	579.241
Silverton, at road crossing; top of rail	584.9
Crow Summit, 0.5 mile west of (2.7 miles east of Silverton), east of and near a large hill, 9 feet left of center of track, in top of large stone; bronze tablet stamped "591 ADJ 1903"	590.973
Crow Summit, in front of station; top of rail	640.9
Sandyville, road crossing; top of rail	598.8
Sandyville, 1 mile east of, near road crossing, on right of track, in northwest corner of northwest abutment of iron county bridge; bronze tablet stamped "594 ADJ 1903"	593.678
Jones crossing; top of rail	602.6
Meadowdale, 300 feet northwest of station, near junction of Biglick road with pike, in face of large rock; bronze tablet stamped "626 ADJ 1903".	626.042
Meadowdale, at road crossing; top of rail	617.2
Leroy, about 300 feet southwest of store and post-office and across Sand Creek, in face of outcrop of rock; bronze tablet stamped "646 ADJ 1903"	646.038
Liverpool, 1.6 miles east of, northwest side of county road, about 220 feet northeast of railroad crossing, in outcrop of rock; bronze tablet stamped "873 ADJ 1903"	873.010

WISEBURG, SOUTHWEST ALONG HIGHWAY, TO SHERMAN.

Cuba, 300 feet north of post-office, on west (opposite) side of road, edge of stream, in top of large bowlder; aluminum tablet stamped "673 GRAFTON 1903"	673.122

EVANS, EAST ALONG RAILROAD AND TURNPIKE, TO POINT 0.5 MILE EAST OF MARSHALL.

Ripley, 2.9 miles west of, 70 feet south of track, east side of road, in top of low rock; bronze tablet stamped "602 ADJ 1903"	601.621
Ripley, railroad crossing at station; top of rail	606
Ripley, court-house square, southwest corner, in top of stone post; bronze meridian tablet stamped "615 ADJ 1903"	614.566
Hereford, 3.4 miles west of, north of road and near sharp bend to south, in shelf of rock; bronze tablet stamped "824 ADJ 1903"	823.894
Hereford, 0.3 mile east of, north of road, in top of large rock; bronze tablet stamped "632 ADJ 1903"	631.750
Frozencamp, in north end of west abutment of covered bridge over Big Run; bronze tablet stamped "641 ADJ 1903"	641.091
Marshall, 0.5 mile east of, north of road, in face of large rock; bronze tablet stamped "697 ADJ 1903"	696.931

RIPLEY, NORTH ALONG ROAD, TO SANDYVILLE.

Ripley, 3.25 miles north of, 0.4 mile south of crossroads and summit, east of road, in top of outcrop of rock; bronze tablet stamped "729 ADJ 1903".	728.595
Mentor, 1.4 miles north of, in second step at northeast side of northwest abutment of covered bridge over Sandy Creek; bronze tablet stamped "591 ADJ 1903"	591.050

LEROY, NORTHEAST ALONG ROAD, TO PEEWEE.

Leroy, 2.65 miles north of, east of road, near dwelling, in shelf of outcrop of rock; bronze tablet stamped "961 ADJ 1903"	961.200

[illegible]

[illegible] EAST ALONG HIGHWAY TO [illegible]

	Feet.
[illegible]	691.5
[illegible] mile east [illegible] west bank [illegible] northwest corner of large rock; bronze tablet stamped "[illegible] ADJ 1903"	694.343
[illegible]	694.2
[illegible] mile west [illegible] [illegible] over Spring Branch; bronze tablet stamped "[illegible] ADJ 1903"	684.051
[illegible]	706.5
[illegible] mile east [illegible] north abutment of county road; bronze tablet stamped "[illegible] ADJ 1903"	702.389
[illegible]	698.7
[illegible] mile west [illegible] north side of county road, in face of large rock; bronze tablet stamped "[illegible] ADJ 1903"	916.946
[illegible]	719.2
[illegible] mile northeast [illegible] east end of railroad, in west abutment of county road bridge over Spring Rock; aluminum tablet stamped "[illegible] ADJ 1903"	725.750
[illegible] mile east [illegible] Pierce, in top of large rock south of road; bronze tablet stamped "[illegible] ADJ 1903"	1,071.304
Pierce, [illegible] mile east [illegible] north side of road, in northwest corner of large rock; bronze tablet stamped "742 ADJ 1903"	741.983

ELKHART, WEST ALONG HIGHWAY TO SPENCER, THENCE SOUTHEAST TO CRESTON.

	Feet.
Elkhart, 4.2 miles west of, in northeast end of southeast abutment on bridge east of iron bridge over Rock Run; bronze tablet stamped "650 ADJ 1903"	669.994
Elkhart, 4.6 miles west of, left side of road, in root of chestnut tree 20 inches in diameter; rail Wabash Railroad bench mark	656.76
Burning Springs, 2.5 miles southeast of, 90 feet northwest of a deep hollow, southwest side of road, in top of large rock; bronze tablet stamped "656 ADJ 1903"	656.130
Creston, 0.11 mile east of, north side of road, in outcrop of rock; bronze tablet stamped "701 ADJ 1903"	701.050

CRESTON, SOUTH ALONG HIGHWAY TOWARD RICHARDSON.

Richardson, 4 miles north of, south side of road, south side of West Fork, north angle of very large rock; bronze tablet stamped "657 ADJ 1903".	658.612

PEEWEE, NORTHEAST ALONG ROAD, VIA ZACKVILLE, TO ROVER.

Peewee, 0.47 mile northeast of, north of road, in face of ledge of rock; bronze tablet stamped "692 ADJ 1903"	692.156
Zackville, 1 mile northeast of, northeast of road, in face of outcrop of rock; bronze tablet stamped "662 ADJ 1903"	662.195

SPENCER, WEST ALONG TURNPIKE, TO MARSHALL.

Spencer, 3.1 miles west of, 40 feet northwest of center of turnpike, in face of outcrop of rock; bronze tablet stamped "854 ADJ 1903"	853.832
Reedyville, 0.9 mile east of, at center of forks of road; iron post stamped "753 ADJ 1903"	752.703
Peniel, triangle at forks of road, in top of large rock; bronze tablet stamped "739 ADJ 1903"	739.212

BURNING SPRINGS, SOUTH ALONG ROAD, TO SPENCER.

	Feet.
Evelyn, 1 mile north of post-office, 85 feet southwest of fork of road to Creston, in rock west of road; bronze tablet stamped "660 ADJ 1903"..	660.064
Evelyn, 2.5 miles south of, 0.2 mile south of Spring Creek crossing, in projecting cliff 10 feet west of road; bronze tablet stamped "745 ADJ 1903".	744.661
Millard post-office, 1.2 miles south of, north of road at reversed bend northeast of Spring Creek, in large rock; aluminum tablet stamped "696 ADJ 1903".....	696.001
Wellington post-office, 1 mile southeast of, east of private road at fork, in large rock; bronze tablet stamped "704 ADJ 1903".....	704.208

KENNA, OTTER, WALTON, AND WINFIELD QUADRANGLES.

CALHOUN, CLAY, JACKSON, KANAWHA, MASON, PUTNAM, AND ROANE COUNTIES.

Leveling in Winfield quadrangle in 1906 by C. H. Burns, in Walton and Kenna quadrangles in 1906 by C. H. Burns and E. S. Dawson, and in Otter quadrangle in 1906 by E. S. Dawson and D. D. Teets, and in 1908 by E. S. Dawson.

OTTER QUADRANGLE.

BEECH, SOUTHEAST ALONG ROAD, VIA MINNORA AND BIG OTTER, TO POINT 4 MILES SOUTH OF BIG OTTER; THENCE WEST, VIA NEWTON, TO AMMA.

	Feet.
Beech, 2.72 miles south of, 30 feet east of Beech Fork, 0.15 mile north of store and dwelling, in large rock; aluminum tablet stamped "766"....	765.489
Minnora post-office, 1.9 miles west of, 1,000 feet west of head of Fink Run, 5 feet south of road along stream bed, 700 feet east of house on right of road, at mouth of deep hollow, at foot of hill, in large stone; aluminum tablet stamped "911".....	911.253
Minnora, 1.2 miles south of, 15 feet east of road, 25 feet west of West Fork, Little Kanawha River, in top of large stone; aluminum tablet stamped "795".....	794.243
Minnora, 4.5 miles south of, west of road, 30 feet northeast of house, at sharp bend in road, in pointed rock; aluminum tablet stamped "835"..	834.982
Stinson, 2 miles southeast of, 200 feet northeast of house, south of road at bend to south, on Stinson Creek, in large bowlder; aluminum tablet stamped "921".....	920.315
Nebo, 1.8 miles south of post-office, west of road, 100 feet northeast of house, near head of Stinson Lick (emptying into Otter Creek), in rock; aluminum tablet stamped "993".....	992.647
Big Otter, 1.8 miles south of post-office, south of road, 400 feet southwest of house, 600 feet west of deep hollow, in outcrop of cliff; aluminum tablet stamped "868".....	867.886
Steer Run, 400 feet northwest of mouth of, north of road up left-hand fork of Rush Run (emptying into Otter Creek), in outcrop of rock; aluminum tablet stamped "950".....	949.571
Newton, 4.4 miles southeast of, north of road, near mouth of Summers Fork, in rock cliff; aluminum tablet stamped "773".....	772.591
Newton, 2.4 miles southeast of, north of road, 890 feet north of Cutoff Run, 150 feet east of Right Fork of Big Sandy Creek, 3 feet above level of road, in sandstone ledge; aluminum tablet stamped "746".....	745.526
Newton, 2.4 miles southwest of, 115 feet northwest of road forks, 150 feet northwest of Big Sandy Creek, opposite mouth of Granny Creek, in rock cliff; aluminum tablet stamped "711".....	710.325

	Feet.
Bloomington, 0.2 mile south of post-office, west edge of road, east edge of woods, in hollow, 20 feet west of Big Sandy Creek, in top of rock outcrop; aluminum tablet stamped "692"	691.694

BENCH MARK ON LEFTHAND RUN.

Lefthand, 1.3 miles south of post-office, 1.2 miles north of mouth of Shaver Fork, 300 feet southeast of Lefthand Run, southeast of road, in sandstone; aluminum tablet stamped "760"	759.939

BIG OTTER, SOUTHEAST, TO MOUTH OF DOG RUN ON BUFFALO CREEK.[a]

Big Otter, 5 miles south of, 1.2 miles south of mouth of Rush Run, east of road, 250 feet northeast of house, in hollow across Otter Creek, in rock; aluminum tablet stamped "798"	797.782
Ivydale post-office (Otter Station), in southwest pier of iron suspension county bridge across Elk River; aluminum tablet stamped "758"	757.459

RAND, EAST ALONG COAL AND COKE RAILROAD, TO KING.[b]

Rand, 0.12 mile east of, 0.74 mile west of King, 10 feet south of Coal and Coke Railroad track, inside of wide curve near fill and deep hollow to south, in sandstone outcrop; aluminum tablet stamped "654"	654.241
King, in front of station; top of rail	653.7

WALTON QUADRANGLE.

AMMA, WEST ALONG ROAD, TO KETTLE.

Amma, 0.25 mile east of post-office, west of road, 150 feet northwest of Big Sandy Creek, 100 feet west of bridge over mouth of Lefthand Run, in rock; aluminum tablet stamped "696"	695.672
Amma, 2.6 miles southwest of (0.2 mile northeast of Roadside schoolhouse), 30 feet west of Garner Branch, opposite blacksmith shop, northwest of road, in outcrop of rock; aluminum tablet stamped "657"	657.094
Wellford, 160 feet west of post-office, on west side of Lefthand Creek at mouth of Lick Branch, southwest of footbridge over Lefthand Creek, west of road, in outcrop; aluminum tablet stamped "625"	624.527
Wellford, 3.6 miles northwest of 2.2 miles west of mouth of Gabes Creek, south of road, 200 feet north of Gabes Creek and house in hollow, 0.85 mile east of summit, in top of rock bowlder; aluminum tablet stamped "917"	916.263
Wellford, 4 miles west of, 350 feet northwest of foot of mountain, 25 feet north of Small Run, 0.7 mile east of Trail Branch of Little Sandy Creek, north of road, in outcrop of stone; aluminum tablet stamped "803"	803.027
Hunt, 3.2 miles northeast of, 150 feet east of hollow and house, 90 feet north of Little Sandy Creek, north edge of road, in bowlder; aluminum tablet stamped "692"	691.616
Hunt, 125 feet north of post-office, in southwest corner of foundation of store, at forks of road and mouth of Pocatalico Fork of Little Sandy Creek, north of road; aluminum tablet stamped "658"	657.534
Kettle, 300 feet south of post-office, west of road, east of Hunt Fork of Green Creek, 420 feet south of Green Creek, in blue sandstone; aluminum tablet stamped "672"	671.475

[a] The closure error of this line was excessive, but the line has been adjusted by arbitrarily throwing 1 foot at the south edge of Gassaway quadrangle.

[b] Leveling of 1908 by E. S. Dawson.

AMMA, NORTHWEST ALONG ROAD TO SPEED, THENCE SOUTHWEST TO HARMONY.

	Feet.
Lefthand, 1.65 miles northwest of, north of road, 400 feet east of hollow to north, in sandstone outcrop; aluminum tablet stamped "868"	866.211
Lefthand, 4.5 miles northwest of, south of road, on north bank of Pocatalico River, in sandstone outcrop; aluminum tablet stamped "771"	769.831
Hammack, 425 feet north of post-office, at mouth of Shammon Branch, in sandstone outcrop; aluminum tablet stamped "734"	732.761
Hammack, 3 miles north of, 100 feet east of Rush Creek, north of road, in sharp bend of road in field, 60 feet north of center of road, in bluestone outcrop; aluminum tablet stamped "751"	749.338
Rushville, 1.65 miles northwest of, in field 220 feet south of road, west of large flat hollow and small mill, in sandstone outcrop; aluminum tablet stamped "907"	905.500
Speed, 420 feet west of road forks at post-office building and mouth of Buffalolick Run (emptying into Spring Creek), south of Spring Creek road, in sandstone outcrop; aluminum tablet stamped "794"	792.342
Gandeeville, east of post-office, on property of R. C. Blasser, 50 feet south of road forks, in sandstone outcrop; aluminum tablet stamped "803"	801.994
Gandeeville, 3.15 miles west of, south of road opposite road forks, east of house and store, in sandstone outcrop; aluminum tablet stamped "764"	762.744
Harmony, 1.2 miles north of, 200 feet west of mouth of Wolfcamp Run, at road forks, 60 feet north of road, inside of field on property of T. W. Hughes, in front of house on south side of road, in sandstone outcrop; aluminum tablet stamped "748"	746.533

KENNA QUADRANGLE.

HARMONY, WEST ALONG ROAD VIA BELGROVE, TO KENNA; THENCE SOUTHWEST TO MOUTH OF STUMPY RUN 4.4 MILES WEST OF LIBERTY.

Higby, 1.5 miles southeast of, south of road and bank of Higby Creek, 750 feet above right fork of Higby Creek, in sandstone; aluminum tablet stamped "738"	737.812
Belgrove, 1 mile southeast of, on north side of road, on bank 70 feet east of private road up deep hollow to north of house and blacksmith shop, in sandstone outcrop; aluminum tablet stamped "704"	703.367
Belgrove, 2 miles southwest of, 40 feet south of center of road in field, 60 feet north of house, in sandstone outcrop; aluminum tablet stamped "817"	816.152
Kenna, 1.5 miles east of, north of road, 700 feet west of schoolhouse, 380 feet east of road fork to north, in sandstone outcrop; aluminum tablet stamped "747"	746.350
Emma, west of road, in corner stone of church; aluminum tablet stamped "980"	979.454
Liberty, 100 feet from center of road, opposite post-office, in stone wall of cellar (property of J. M. Carney) on west side; aluminum tablet stamped "779"	777.937

HUNT, NORTH TO KETTLE.

Hunt, 3 miles north of, west of Pocatalico Fork, opposite house and west of hollow, 1 mile east of mountain, north of road, in bluestone; aluminum tablet stamped "809"	808.569

KETTLE, WEST ALONG ROAD, TO NEAR SISSONVILLE; THENCE NORTHWEST, TO KENNA.

	Feet.
Island Branch, 0.2 mile east of post-office, north of road, 40 feet north of Pocatalico River, 90 feet west of Camp School, in rock; aluminum tablet stamped "656"	655.797
Island Branch, 3.1 miles southwest of, 50 feet west of Pocatalico River, 0.2 mile north of Emma Bell schoolhouse, east of road, in sandstone outcrop; aluminum tablet stamped "646"	645.376
Carney, 0.5 mile west of post-office, north of road, 150 feet north of Pocatalico River, 0.1 mile west of Victory schoolhouse, in bowlder; aluminum tablet stamped "635"	635.055
Sissonville, 3 miles north of, in south end of east abutment of iron bridge over Left Fork of Pocatalico River; aluminum tablet stamped "625"	625.393
Loop, 2.65 miles northwest of 1 mile southeast of, Goldtown, 100 feet west of mouth of Dudden Fork, in east end of north abutment of iron bridge; aluminum tablet stamped "643"	643.148
Goldtown, 1.5 miles northwest of, east of road, 40 feet from center of road, road forks to north, in sandstone foundation of Watts Chapel; aluminum tablet stamped "671"	670.471
Kenna, 0.8 mile south of, east of road, 380 feet south of house to west, in sandstone outcrop; aluminum tablet stamped "872"	871.772

SISSONVILLE, SOUTHWEST 3.4 MILES (SINGLE SPUR LINE).

Sissonville, 90 feet south of north end west side of iron bridge over Pocatalico River; aluminum tablet stamped "624"	624.086
Sissonville, 3.45 miles southwest of, 50 feet west of road, 100 feet west of Pocatalico River, 0.9 mile north of Derrick Creek, in garden of old house, in bowlder; aluminum tablet stamped "615"	615.245

WINFIELD QUADRANGLE.

LEON, SOUTH ALONG EAST SIDE OF KANAWHA RIVER, TO WOODS STATION, THENCE ACROSS RIVER AND WEST, TO ALBATROSS.

Arbuckle, 0.1 mile south of, 10 feet east of road, in sandstone; aluminum tablet stamped "608"	608.410
Arbuckle, 2.3 miles south of, in bridge abutment on northeast corner of bridge over Arbuckle Creek; aluminum tablet stamped "567"	567.040
Buffalo, in stone door sill in west end of M. E. Church, South; aluminum tablet stamped "580"	579.846
Woods station (3.8 miles south of Buffalo), east of road opposite fork west to Kanawha River ford to Fraziers Bottom, in sandstone; aluminum tablet stamped "590"	590.290

WOODS STATION, SOUTHEAST ALONG KANAWHA RIVER, TO REDHOUSE SHOALS; THENCE NORTHEAST, ALONG HIGHWAY, TO PARADISE; THENCE NORTH TO ELMWOOD; THENCE WEST, TO GRIMMS LANDING.

Redhouse Shoals, in northeast end of county bridge abutment; aluminum tablet stamped "570"	569.670
Redhouse Shoals, 3.5 miles northeast of, 0.4 mile west of a road summit, 20 feet south of center of road, in sandstone; aluminum tablet stamped "967"	966.730
Confidence, 0.8 mile east of, 15 feet north of center of road, in sandstone; aluminum tablet stamped "853"	853.331
Paradise, 2.3 miles north of, east side of road at crossroads, north of Cherry Fork of Eighteenmile Creek, in sandstone; aluminum tablet stamped "660"	659.852

	Feet.
Paradise, 4.5 miles north of, in abutment of south end of county bridge over Eighteenmile Creek; aluminum tablet stamped "635"	634.661
Tribble, 2.2 miles southeast of, 15 feet north from center of road, south of house, hollow north and south, in sandstone; aluminum tablet stamped "713"	713.223
Elmwood, 0.7 mile east of post-office, on northeast corner of road forks, in sandstone; aluminum tablet stamped "624"	625.549
Grimms Landing, 3 miles northeast of, north of road, south of house, in sandstone; aluminum tablet stamped "624"	625.868

HUNTERSVILLE AND NICHOLAS 30′ QUADRANGLES.

CLAY, KANAWHA, NICHOLAS, FAYETTE, AND GREENBRIER COUNTIES.

These descriptions and elevations are republished from the Appendix to the Twenty-first Annual Report of the Director of the United States Geological Survey, with a few additions. No correction has yet been made of the elevations for the reason that closures made have been of contrary signs.

The leveling was mostly done in 1898–99, by Hargraves Wood. A few additional bench marks were set in 1906 by D. D. Teets and E. S. Dawson.

NICHOLAS QUADRANGLE.

ZELA, EAST TO SUMMERSVILLE.

	Feet.
Zela, 0.1 mile east of, 300 feet west of Crosslanes road, in field 50 feet south, in large sandstone rock; aluminum tablet stamped "1267 KNWA"	1,267.646
Summersville, east side of door in base of pilaster in front of court-house; aluminum tablet stamped "1894 KNWA"	1,893.808

ZELA, SOUTH, VIA KESLERS CROSSLANES AND CARNIFAX FERRY, TO MOUNT LOOKOUT; THENCE EAST TO FOWLER KNOB.

Keslers Crosslanes, 600 feet south of store, and crossroads, 100 feet south of S. P. Campbell's house, west of road, in ledge; brass bolt stamped "1567 KNWA"	1,567.409
Mount Lookout, 1 mile southeast of, 250 feet south of schoolhouse, east of road, in ledge of rock; aluminum bolt stamped "2069 KNWA"	2,069.402
Fowler Knob, 400 feet south of, east of road, just north of small branch, in large ledge of rock; aluminum bolt stamped "2195 KNWA"	2,195.382

FOWLER KNOB, SOUTHWEST ALONG ANGLINS CREEK, TO RUSSELLVILLE; THENCE SOUTHEAST OVER MOUNTAIN TO RIVERSIDE.

Miller's ferry (over Meadow River), 0.1 mile north of, east of river, west of road, in ledge of rock; aluminum bolt stamped "1905 KNWA"	1,904.943
Russellville, 90 feet north of, east of road, west of river, in ledge of rock; aluminum tablet stamped "1900 KNWA"	1,900.123
Riverside (at Meadow River), 150 feet northwest of, 800 feet east of ford, west of road, between house and barn, in one of several ledges of rock; aluminum bolt stamped "2324 KNWA"	2,324.014

RIVERSIDE, EAST, VIA BURDETT SCHOOLHOUSE, TO M'CLUNGS; THENCE NORTH TO SNOW HILL; THENCE NORTHWEST TO FOWLER KNOB.

Snow Hill, 8.8 miles southeast of, at northwest intersection of Nicholas road and road to Nutterville, 500 feet north of Grig McClungs's house, in sandstone rock; bronze tablet stamped "3392 KNWA"	3,391.855

	Feet.
Snow Hill, 6.5 miles southeast of, at angle of Greenbrier-Nicholas county line; top of corner stone	3,129.000
Snow Hill, 200 feet southwest of post-office, 535 feet north of road running west, west of Nicholas road, in rock; aluminum bolt stamped "2943 KNWA"	2,943.583

1.6 MILES NORTHWEST OF SNOW HILL, NORTHEAST TO OPHELIA; THENCE SOUTHEAST TO BEACH KNOB; THENCE SOUTHWEST TO M'CLUNGS.

Ophelia, 0.75 mile south of, 1,500 feet west of crossroads and church, west of farm road, 50 feet north of Summersville road, in rock; bolt stamped "2587 KNWA"	2,587.132
Lile, opposite post-office, west of road, 100 feet west of McMillion Creek, in rock; copper bolt stamped "3121 KNWA"	3,121.290
Grassy Knob, at trail fork, 10 feet north of sign, in large flat rock; aluminum bolt stamped "3581 KNWA"	3,585.7

LEIVASY, NORTHEAST, ROAD UP CROSSING GRASSY CREEK.

Grassy Creek, about 900 feet east of creek crossing, on north side of road up Grassy Creek, in rock; aluminum tablet stamped "2426 KNWA"	2,425.873

BEECH KNOB, SOUTH TO DUO.

Duo, 0.5 mile northwest of, 200 feet north of forks of road to Rupert, 100 feet north of branch, 50 feet east of road, near small house; in bowlder; bolt stamped "3206 KNWA"	3,206.454

SUMMERSVILLE, NORTH UP MUDDLETY CREEK TO HOOKERSVILLE.

Hookersville, 200 feet west of road to Powell Mountain, at intersection of road up Muddlety Creek, in field, in rock; aluminum tablet stamped "1859 KNWA"	1,859.496

MUDDLETY, NORTHWEST ALONG ROAD TO BUFFALO CREEK (DOUBLE-HUB SPUR LINE).

Muddlety, 7.3 miles northwest of, at crossing, about 2,000 feet north of Beech Fork, south of road, opposite Liberty Bowl schoolhouse, in rock; aluminum tablet stamped "1747 KNWA"	1,746.593
Enoch, 3.8 miles northwest of, northwest side of Buffalo Creek, opposite point 60 feet north of mouth of Dog Run, in rock cliff; aluminum tablet stamped "826 KNWA"[a]	826.124

BUFFALO CREEK TO LOW GAP.[b]

Enoch, 3.8 miles northwest of, northwest side of Buffalo Creek, 90 feet north of Dog Run, in bowlder; aluminum tablet stamped "828"	826.540
Ivydale post-office, 9.1 miles southeast of, 1.1 miles northwest of mouth of Dog Run, west of sawmill, northeast of road, in top of large bowlder; aluminum tablet stamped "857"	855.608
Ivydale, 5.8 miles southeast of, north of road from Sutton to Clay, on northeast slope of hill, south of Low Gap, in rock outcrop; aluminum tablet stamped "1236"	1,234.884

HOOKERSVILLE, NORTHEAST OVER POWELL MOUNTAIN TO BIRCH RIVER; THENCE EAST TO WELCH GLADE; THENCE SOUTHWEST TO CRAIGSVILLE.

Birch River, 4.2 miles southwest of Powell Mountain, opposite road to Strange Creek, in small ledge of rock; aluminum bolt stamped "2249 KNWA"	2,249.18

[a] Reported removed in 1906. Hole still remains.

[b] Three bench marks set in 1906, 2 by E. S. Dawson and 1 by D. D. Teets, levelmen, under E. I. Ireland, topographer. The elevations are by single line, corrected to agree with the datum of this list and are 1 foot less than those brought by single line on Minnora quadrangle.

Birch River, about 300 feet north of post-office, east of Powell Creek, about 0.25 mile north of mouth of Powell Creek, opposite Ivan Bros. & Brown's store, in outcrop of rock; aluminum tablet stamped "1108 KNWA"..... Feet. 1,108.365

Boggs, near post-office, 250 feet east of school, 20 feet north of road, in outcrop of rock; bronze tablet stamped "1555 KNWA"..... 1,555.35

Welch Glade, about 1 mile northwest of, 725 feet southeast of road from top of mountain to Cowen and Glade Run; about 500 feet southeast of house and 0.25 mile northwest of church on east side of road, in rock; bronze tablet stamped "2253 KNWA"..... 2,253.310

Lanes Bottom (near Camden on Gauley), at "The Camden" in west side in pier to porch; bronze tablet stamped "2062 KNWA"..... 2,062.025

Craigsville, near east end of, 670 feet east of Cranberry road and hotel, north of road in front of Macon Bose's house; bronze tablet stamped "2288 KNWA"..... 2,288.157

CRAIGSVILLE, UP BEAVER CREEK TO DELPHI; THENCE WEST DOWN MUDDLETY CREEK TO HOOKERSVILLE.

Hookersville, 5 miles east of, 225 feet east of fork of Muddlety, at crossing of Right Hand Fork, north of road west of crossing, in overhanging rock; aluminum tablet stamped "2005 KNWA"..... 2,004.842

CRAIGSVILLE, SOUTHEAST, VIA WOODBINE AND RICHWOOD, TO MANNING KNOB.

Woodbine, 4.5 miles southeast of, on west side of Greenbrier road, south of trail running west, in hollow near maple tree, in rock; bronze tablet stamped "2969 KNWA"..... 2,969.33

Richwood, 1.75 miles south of, at Greenbrier-Nicholas county line; top of stone..... 2,874.02

HUNTERSVILLE QUADRANGLE.

MANNING KNOB, SOUTH TO GRASSY KNOB; THENCE WEST TO DUO.

Richwood, 7.75 miles southeast of, about 2,350 feet southeast of Manning Knob, northeast side of road, 240 feet from foot of descent from Manning Knob going southeast, in large rock; aluminum bolt stamped "3709 KNWA"..... 3,709.043

Richwood, about 13.75 miles southeast of, southwest of Greenbrier road, 795 feet northwest of road to Duo, in rock; aluminum tablet stamped "4116 KNWA"..... 4,116.433

CLAY, CLENDENIN, FAYETTEVILLE, AND MONTGOMERY 15′ QUADRANGLES (KANAWHA FALLS 30′ QUADRANGLE).

CLAY, FAYETTE, KANAWHA, AND NICHOLAS COUNTIES.

Leveling in Clay and Fayetteville quadrangles in 1898 by Hargraves Wood; in Clendenin and Montgomery quadrangles in 1907 by Orr Meredith; in Montgomery quadrangle in 1908 by E. S. Dawson; and in 1908 in all by C. M. Bennett.

CLAY 15′ (KANAWHA FALLS 30′) QUADRANGLE.

ELK CREEK, EAST VIA LOCKWOOD ON OTTER CREEK, TO ZELA.

Lockwood, 0.1 mile east of, north of road opposite L. N. Simm's house, 200 feet east of R. L. Dickson's house, at east foot of Summers hill, in ledge of rock; bronze tablet stamped "1088 KNWA"..... Feet. 1,087.525

KING, EAST ALONG COAL AND COKE RAILWAY, TO CLAY; THENCE SOUTHEAST, ALONG BUFFALO CREEK AND GAULEY RAILROAD, TO MOUTH OF SAND FORK.

	Feet.
King station, 0.44 mile east of, 1.18 miles west of Procious post-office, 10 feet north of railroad, on large sandstone bowlder; chiseled square; marked "655"	654.89
Procious (Camp station), 0.35 mile east of post-office, 3.91 miles west of Shelley Junction station, 10 feet south of railroad, on short tangent, nearly opposite frame dwelling of Mr. Walker, on sandstone bowlder, chiseled square; marked "655"	655.12
Procious, 0.97 mile east of, 3.29 miles west of Shelley Junction station; 12 feet south of railroad, along long tangent, 1,500 feet east of point opposite dwelling house on north of track, in sandstone outcrop; aluminum tablet stamped "658"	657.821
Shelley Junction, 0.91 mile west of, 10 feet south of railroad, inside of long, sharp curve, nearly opposite mouth of creek on north side of river, on large sandstone bowlder, chiseled square; marked "665"	665.04
Shelley Junction, 0.39 mile west of, 10 feet southwest of railroad, on 1,000-foot tangent, 380 feet west of switch near Shelley Junction, nearly opposite mouth of Big Laurel Creek, in sandstone outcrop; aluminum tablet stamped "666"	666.183
Angeline, 1.08 miles east of post-office, 1.07 miles west of Birch station, 30 feet south of railroad, just west of long, sharp curve in track, on sandstone bowlder, chiseled square; marked "667"	666.43
Eldorado, 2.03 miles west of post-office, 30 feet south of railroad, on outside of long curve, 250 feet east of railroad crossing, in sandstone outcrop; aluminum tablet stamped "679"	678.505
Dorfee, 1 mile east of station, 1.02 miles west of Elkhurst station, 10 feet south of railroad, along short tangent, 380 feet east of point opposite dwelling on north of track, in sandstone outcrop; aluminum tablet stamped "682"	682.046
Yankee Dam, 0.54 mile east of post-office, 3.4 miles west of Leatherwood station, 10 feet north of railroad, 100 feet west of south end of suspension tram bridge over Elk River to sawmill, on solid sandstone bowlder, chiseled square; marked "690"	689.90
Yankee Dam, 1.07 miles east of post-office, 2.33 miles west of Upper Leatherwood station, 12 feet south of railroad on short tangent, at mouth of small hollow to right, at west end of small fill, in solid sandstone bowlder; aluminum tablet stamped "697"	697.018
Upper Leatherwood, 200 feet west of station, in north end of east abutment to three-span plate-girder bridge over Leatherwood Creek; aluminum tablet stamped "702"	701.644
Leatherwood station, 1 mile east of (2.07 miles west of Clay), 12 feet south of railroad on short tangent, just east of long curve, nearly opposite deep hollow north of river, on sandstone outcrop, chiseled square; marked "705"	705.11
Clay, corner of Main and Church streets, 10 feet west of northwest corner of Clay County Bank, in monument; bronze tablet stamped "707"	707.122
Clay, 1.02 miles east of post-office, 1.88 miles north of Avoca post-office, on north end of capstone of east pier of Queen truss railroad bridge across Buffalo Creek near mouth, chiseled square; marked "707"	707.43
Avoca, 0.35 mile south of post-office, 5.05 miles north of mouth of Sand Fork, 10 feet east of Buffalo Creek and Gauley Railroad track, on outside of deep curve in railroad and creek, 40 feet east of creek, near bottom of very thick sandstone outcrop; aluminum tablet stamped "725"	724.963

	Feet.
Avoca, 1.29 miles south of post-office, 4.02 miles north of mouth of Sand Fork, 10 feet north of Buffalo Creek and Gauley Railroad track, at west end of deep side-hill cut in sandstone, 50 feet north of creek, on sandstone outcrop, chiseled square; marked "740"	740.44
Sand Fork, 2.13 miles north of mouth, 10 feet east of Buffalo Creek and Gauley Railroad track, on outside of heavy curve of creek and track, 40 feet east of creek, near south end of heavy side-hill excavation in stone, 1,200 feet north of point opposite schoolhouse, at bottom of thick sandstone outcrop; aluminum tablet stamped "771"	771.392
Sand Fork, 1.1 miles north of mouth, on outside of heavy curve in track, 10 feet east of track, 60 feet east of creek, near bottom of thick sandstone outcrop, chiseled square; marked "787"	787.026

UPPER LEATHERWOOD, SOUTH, VIA LEATHERWOOD AND TWENTYMILE CREEKS, TO BELVA.[a]

Leatherwood Station, 200 feet west of, in north end of east abutment to three-span plate-girder bridge across Leatherwood Creek; aluminum tablet stamped "702"	701.644
Morocco, in front of post-office; top of rail	714.0
Morocco, 0.48 mile south of post-office, 10 feet east of track, 800 feet south of large sawmill, near house and hollow on left, on large white sandstone bowlder, chiseled square; marked "732"	731.57
Morocco, 2.11 miles south of, 20 feet east of railroad, 500 feet north of small hollow to west, in large sandstone bowlder under cedar tree in west edge of creek; aluminum tablet stamped "798"	797.945
Morocco, 5.58 miles south of, 200 feet west of railroad, 300 feet south of residence of J. A. Summers, 400 feet south of mouth of Henry's Branch to east, in west margin of creek, in flat sandstone bowlder; aluminum tablet stamped "919"	919.085
Morocco, 8.56 miles south of, 30 feet west of county road, about one-third way to top of hill on road from Leatherwood Creek to Twentymile, at Clay-Nicholas county line, in solid sandstone bowlder, among the roots of large leaning beech tree; aluminum tablet stamped "1266"	1,266.199
Vaughan, 7.73 miles northeast of, 12 feet east of edge of creek at road crossing, 600 feet north of mouth of Boardtree Branch, on sandstone bowlder, chiseled square; marked "1019"	1,020.58
Boardtree Branch, 0.82 mile west of mouth, 6.78 miles northeast of Vaughan post-office, 10 feet east of narrow-gage railroad track, 30 feet east of creek in sharp bend of stream, on outside of long curve in railroad track, in rock; aluminum tablet stamped "993"	994.401
Boardtree Branch, 2.82 miles west of, 4.88 miles northeast of Vaughan post-office, 20 feet south of track, at north edge of county road at creek crossing, in root on north side of leaning white-oak tree, spike; marked "929" (elevation 7.8 feet above low water at crossing)	930.07
Vaughan, 3.8 miles northeast of, 10 feet north of railroad, 300 feet north of county road, 350 feet north of creek, in solid inclined sandstone bowlder; aluminum tablet stamped "904"	905.646
Vaughan, 1.59 miles northeast of, 10 feet north of railroad, 40 feet north of sharp curve in creek, near road crossing, 600 feet west of point opposite dwelling, 2 feet below coal horizon, on sandstone outcrop, chiseled square; marked "860"	861.08
Vaughan, 0.22 mile east of post-office, at upper side of county road, 50 feet north of mouth of hollow extending northeast to Walker Knob, near north end of lumber yard in Vaughan, 30 feet north of Chesapeake and Ohio Railway track, in sandstone outcrop; aluminum tablet stamped "810"	811.120

[a] The closure error of this line was excessive, but is adjusted by throwing 1 foot at the county line and distributing a remaining 0.4 foot.

	Feet.
Vaughan, 0.8 mile southwest of, in north edge of creek, 20 feet south of Chesapeake and Ohio Railway, 150 feet north of county road, 1,200 feet east of milepost marked "G–12" on east side and "G–13" on west, on large bowlder, chiseled square; marked "789"	790.40
Vaughan, 3.3 miles southwest of, in railroad cut, 10 feet north of railroad, opposite mouth of Dorsey Branch, 250 feet north of residence of C. D. Backus, in face of thick sandstone outcrop; aluminum tablet stamped "739"	740.718
Vaughan, 3.8 miles southwest of, 3.89 miles northeast of Belva station, 10 feet north of railroad, 60 feet north of creek and road, nearly opposite residence on south side of creek, 60 feet west of north end of wooden footbridge across Twentymile Creek, on sandstone outcrop; chiseled square, marked "725"	726.48

CLENDENIN 15′ (KANAWHA FALLS 30′) QUADRANGLE.

POINT 1.3 MILES NORTHEAST OF COAL FORK STATION ON CAMPBELL CREEK RAILROAD, NORTHEAST, VIA FIVEMILE FORK AND RIGHT FORK OF BLUE CREEK, TO POINT 1.52 MILES NORTHEAST OF QUICK; THENCE SOUTHEAST UP BLUE CREEK, MIDDLE FORK, AND POND FORK, TO POND GAP; THENCE SOUTHWEST TO WARD STATION.

Fivemile Fork, 0.43 mile north of mouth, 125 feet northeast of house, north of road, in sandstone bowlder; aluminum tablet stamped "719"	717.966
Quick, 1.3 miles west of, 0.25 mile west of fork of road north to Coco, between road and Right Fork of Blue Creek, on south edge of road, in sandstone bowlder; aluminum tablet stamped "830"	829.753
Quick, 2.9 miles east of, 0.2 mile east of railroad crossing, in east end of rock cliff lying along railroad east of Sandlick Branch; aluminum tablet stamped "718"	717.307
Middle Fork, 0.5 mile west of station, 0.4 mile east of Rockcamp Fork, in masonry at west end of railroad bridge; aluminum tablet stamped "768"	767.601
Middle Fork, 2.38 miles southeast of, 3.25 miles northwest of Blakeley, 0.21 mile southeast of Turner Fork, at north end of railroad trestle, creek and road at foot of cliff, in rock ledge at south side of track; aluminum tablet stamped "865"	863.469
Blakeley, 0.64 mile north of station, south of track at Kanawha and West Virginia Railroad crossing, 4 feet above track, in sandstone cliff; aluminum tablet stamped "1078"	1,075.616
Blakeley, in front of station; top of rail	1,112.5
Mammoth, 3.75 miles northeast of, 300 feet up from foot of hill at head of Hurricane Fork of Kelly Creek, north of road, in sandstone ledge; aluminum tablet stamped "1273"	1,270.758

POINT 1.52 MILES NORTHEAST OF QUICK POST-OFFICE, NORTH ALONG PUBLIC HIGHWAYS, VIA FALLING ROCK CREEK AND COAL AND COKE RAILWAY, TO WELLFORD.

Odell, east of road, in southwest corner of stone foundation to dwelling; aluminum tablet stamped "1215"	1,214.077
Odell, 3.06 miles northeast of, 350 feet north of company store at mouth of Evans Fork of Falling Rock Creek, 60 feet north of road to Apgah at foot of hill; in large sandstone; aluminum tablet stamped "?"	794.464
Weir, 2.9 miles south of, at north side of creek bottom, 250 feet north of Falling Rock Creek, 0.38 mile east of cannel-coal mine, in bowlder; aluminum tablet stamped "714"	713.929

	Feet.
Weir, 0.16 mile south of post-office, 400 feet south of trestle over Laurel Fork, creek on opposite side of track, north of railroad, in sandstone rock; aluminum tablet stamped "647"	646.652
Reamer, 1,600 feet west of, south of Coal and Coke Railway track, in capstone of viaduct over Leatherwood Creek; aluminum tablet stamped "618"	617.454
Clendenin, 1.14 miles north of, near ford crossing to house on east bank of Big Sandy Creek, west of road near foot of bank, in sandstone outcrop; aluminum tablet stamped "624"	623.389

CLENDENIN, EAST ALONG COAL AND COKE RAILWAY, TO RAND.

Clendenin, 0.33 mile north of, 600 feet north of dwelling, at upper side of road up Big Sandy Creek, on sandstone outcrop, chiseled square; painted "621"	620.80
Turner, in front of station; top of rail	636.3
Turner, 0.72 mile east of station, 1.1 miles west of Queen Shoals station, 12 feet south of tracks, nearly opposite west house in group of four, in brown sandstone bowlder; aluminum tablet stamped "645"	644.117
Barren Creek, 0.26 mile west of post-office, 20 feet south of track, opposite east end of warehouse near lampblack factory, on sandstone bowlder, chiseled square; marked "644"	643.59
Porter, 0.82 mile west of station, 10 feet southwest of track, in blue sandstone outcrop; aluminum tablet stamped "646"	645.663
Porter, in front of station; top of rail	644.4
Porter, 0.4 mile east of station, 10 feet south of track, 300 feet east of house on opposite side of track, on brown sandstone bowlder, chiseled square; marked "648"	648.08

FAYETTEVILLE 15′ (KANAWHA FALLS 30′) QUADRANGLE.

LOCK 2, EAST ON KANAWHA AND MICHIGAN RAILWAY, TO GAULEY.

Kanawha River Lock 2, top of coping; U. S. Engineer Corps elevation 609.75 (recovered by precise levels)	613.808
Kanawha River Lock 2, near north end and in east face of masonry; bronze tablet stamped "614 KNWA" (recovered by precise levels)	613.485
Harewood, 600 feet east of coal tipple, in top of coping at north end of Kanawha and Michigan Railway culvert; aluminum bolt stamped "638 KNWA"	637.328
Kanawha Falls, 180 feet south of flag station of Kanawha and Michigan Railway, 200 feet north of road crossing of railroad, west of track, nearly opposite house of T. W. Farley, in face of rock at base of cliff; bronze tablet stamped "667 KNWA" (U. S. Engineer Corps elevation 662.488, recovered by precise levels)	666.543
Gauley Bridge railway station, at west end of bridge over highway, in south face of abutment at top step of wing wall; aluminum tablet stamped "677 KANAWHA" (recovered by precise levels)	676.543

GAULEY, NORTH ALONG CHESAPEAKE AND OHIO RAILROAD, TO POINT 3 MILES NORTH OF BELVA.

Vanetta, 0.04 mile south of post-office, 0.97 mile north of Gauley Bridge, 10 feet north of railroad, 1,000 feet east of Vanetta coal tipple, 400 feet east of Sand Branch, on large sandstone bowlder; chiseled square, marked "679"	680.60

	Feet.
Gamoca, 0.32 mile south of post-office, 1.08 miles north of Vanetta post-office, 10 feet south of railroad, on south bank of Gauley River opposite mouth of Big Creek, 2,000 feet west of milepost marked "G–4–G–11," in sandstone outcrop; aluminum tablet stamped "684"	685.257
Wyndal, 1.55 miles south of post-office, 1 mile north of Gamoca post-office, 10 feet south of railroad, 1,000 feet west of milepost marked "G–5–G–10," on shaly sandstone outcrop; chiseled square; marked "688"	689.64
Belva, 0.4 mile south of station, 0.6 mile north of Wyndal post-office, in south face of capstone on east end of south abutment of bridge across Gauley River; shank of old bronze tablet (old bench mark which was stamped "711")	710.006
Belva, 2.6 miles northeast of, 20 feet north of railroad, 40 feet south of creek, 220 feet east of point opposite mouth of Bell Creek, on large sandstone bowlder, chiseled square; marked "700"	701.74

BELVA, EAST ALONG GAULEY RIVER, TO LITTLE ELK CREEK.[a]

Belva, 4.8 miles east of, 0.5 mile northeast of mouth of Elk Creek, 15 feet northwest of road, in ledge of rock; aluminum bolt stamped "752 KNWA"	751.506

FAYETTE, NORTH ALONG HIGHWAY, TO LOCKWOOD.

Nuttallburg, 1.47 miles west of, 220 feet west of milepost "Cin.–262," south of track, in very high bowlder; aluminum tablet stamped "924".	923.546
Lansing, 0.36 mile southwest of post-office, east of long overhanging outcrop, 75 feet west of balanced bowlder south of road, 2 feet above grade, in sandstone outcrop north of road; aluminum tablet stamped "1583"	1,582.321
Lansing, 0.77 mile northeast of post-office, 60 feet south of wooden culvert over branch where road turns sharply to east, halfway down hill to Mill Creek, west of road, on sandstone outcrop, chisel cut; marked "1717"	1,716.20
Lansing, 1.5 miles northeast of, 200 feet west of house north of road, on south edge of road, on sandstone ledge, chisel cut; marked "1766"	1,765.75
Lansing, 2.2 miles northeast of, 0.17 mile east of pine grove, at slight hollow to south, 50 feet west of bend to north, south of road, in sandstone outcrop; aluminum tablet stamped "1814"	1,813.142
Hico, 1.5 miles southwest of, 40 feet east of road north leading to Thomas Kinkaid's place, 100 feet west of wooden bridge over branch, 140 feet east of branch, north of road, on sandstone outcrop, chiseled square; marked "1885"	1,884.78
Hico, 0.7 mile west of post-office, 175 feet east of Timber Lake schoolhouse, at south edge of road, on Mill Creek, in sandstone outcrop; aluminum tablet stamped "1955"	1,954.011
Deitz, 3.76 miles southwest of, 300 feet east of turnpike road, north of road, on sandstone outcrop, chiseled square; marked "2034"	2,032.90
Deitz, 1.3 miles south of, 75 feet east of first turn in road below top of hill, ground facing north and opposite side of Osborn Creek to church and school, 130 feet east of house on west side of road, 10 feet west of slight hollow, under white walnut tree, in sandstone bowlder; aluminum tablet stamped "1798"	1,796.962
Deitz, 0.3 mile west of post-office, 150 feet west of branch, 90 feet north of sharp turn to north where road approaches hollow, west of road, on sandstone ledge; chiseled square; marked "1814"	1,813.55

[a] Part of old line to Nicholas quadrangle.

	Feet.
Ramsey, 0.56 mile north of, 30 feet east of Laurel Creek, 600 feet north of Gwinn Branch, opposite side of creek from house, 12 feet west of road, in sandstone bowlder; aluminum tablet stamped "1427"	1,426.438
Lucas, 500 feet northwest of post-office, on north side of Gauley River, 130 feet west of Wood's ferry landing, north of road in huge conglomerate bowlder; aluminum tablet stamped "1006"	1,004.909
Albion, 1.12 miles east of, 125 feet northeast of Pinegrove schoolhouse, 150 feet southwest of wooden bridge over branch, north of road, 1 foot above ground, in sandstone outcrop; aluminum tablet stamped "1306"	1,304.854
Tipton, 0.46 mile southeast of, 90 feet west of short turn to right going down Laurel Fork of Peters Creek, 400 feet northeast of house on left side of creek, west of road, on sandstone outcrop, chiseled point; marked "1332"	1,330.95
Drennen, 0.4 mile south of post-office, 200 feet north of house, on upper side of road, 50 feet southeast of spring by roadside, east of road, on sandstone outcrop, chiseled square; marked "1289"	1,288.07
COTTON HILL, SOUTH ALONG HIGHWAY, TO POINT ON LOOP CREEK 2 MILES WEST OF WRISTON.	
Cotton Hill, 1.14 miles west of, 150 feet south of milepost "Cin 253," 7 feet east of track, in top of large rock; aluminum tablet stamped "771"	770.240
Beckwith, 0.88 mile west of post-office, 4.08 miles east of Dempsey, on north edge of county road, 150 feet west of fork of road to south, nearly opposite deep hollow and schoolhouse, in solid sandstone bowlder; aluminum tablet stamped "1223"	1,221.928
Dempsey, 1.8 miles east of, opposite deep hollow, on north edge of county road, near top of bank, on sandstone outcrop, chiseled square; marked "1321"	1,320.75
Dempsey, 0.98 mile east of post-office, 10 feet northwest of county road, 50 feet northwest of gristmill owned by W. H. Nugen, 20 feet south of blacksmith shop, 200 feet east of Laurel Hill schoolhouse, in sandstone outcrop; aluminum tablet stamped "1325"	1,324.582
Dempsey, at fork of road to south up left fork of Laurel Creek, 200 feet east of Dogged Chapel, on solid sandstone bowlder; chiseled square; marked "1345"	1,344.48
Dempsey, 2.03 miles west of, at north edge of county road, 360 feet from foot of hill on Laurel Creek side, in solid sandstone bowlder; aluminum tablet stamped "1531"	1,530.264
Wriston, 0.73 mile east of post-office, at south edge of county road, opposite and 300 feet from residence of B. W. Settle, on sandstone outcrop, chiseled square; marked "1535"	1,534.69
Wriston, 0.9 mile west of post-office, 4.05 miles southeast of Kincaid post-office, 20 feet north of Deepwater Railroad track, 400 feet south of county road, at east end of rock cut, 600 feet southeast from residence of K. Kincaid, 1,600 feet east of milepost "DW-13," in sandstone bowlder; aluminum tablet stamped "1409"	1,408.031
ROBSON, ON VIRGINIAN RAILWAY FROM MILEPOSTS 7 TO 4.[a]	
Robson, 0.63 mile south of post-office, just south of Underwood's store, 60 feet south of road crossing, 700 feet north of milepost "DW-6," on top stone at west corner of north abutment of bridge across Loop Creek, chiseled square; marked "1000"	999.13
Robson, 1.08 miles north of post-office, 150 feet southwest of Virginian Railway track, 300 feet west of station, 1,200 feet east of milepost "DW-4," in flat sandstone bowlder; aluminum tablet stamped "874"	872.963

[a] Other elevations on this railroad are given in list for Montgomery quadrangle.

DEEPWATER, EAST TO KANAWHA FALLS.

	Feet
Kanawha Falls, 3,000 feet southwest of station, 500 feet west of hollow, on south end of stone culvert, chiseled square; marked "659"	658.

MONTGOMERY 15′ (KANAWHA FALLS 30′) QUADRANGLE.

DICKINSON, SOUTHEAST, TO CABIN CREEK JUNCTION; THENCE SOUTH ALONG CHESAPEAKE AND O RAILROAD AND SOUTHWEST 3 MILES UP COAL FORK.

Cabin Creek Junction, 1 mile south of, east of railroad, and creek, 240 feet north of hollow, 0.3 mile south of mouth of Cabin Creek, in outcrop of sandstone; chiseled square; painted "621"	620.
Dry Branch, 0.7 mile northwest of post-office, north of railroad and river, 40 feet east of trail over point, in sandstone cliff; aluminum tablet stamped "621"	620.
Dry Branch, 1.5 miles southeast of, at south end of cut, east of railroad, 0.1 mile north of coal tipple, on top of outcrop of rock, chiseled square; painted "658"	657.
Sharon, 200 feet west of post-office, 75 feet west of railroad bridge over Cabin Creek, opposite mouth of Paint Branch, between station and Cabin Creek, in second stone in abutment at northeast end of bridge over small run; aluminum tablet stamped "668"	667.
Ohley, 1.2 miles northwest of post-office, west of Chesapeake and Ohio Railway, 400 feet north of mouth of Coal Fork, in outcrop of rock; aluminum tablet stamped "742"	740.
Ohley, 4 miles west of, north of road, in bank, 30 feet off road, 0.1 mile northwest of house, in large rock bowlder; aluminum tablet stamped "919"	917.

POINT 1.95 MILES WEST OF CEDAR GROVE, NORTHEAST UP KELLY CREEK, TO WARD.

Cedar Grove, 1.95 miles west of, in east abutment of railroad culvert; aluminum tablet stamped "618"	617.
Cedar Grove, 1,500 feet east of station, in masonry at west end of culvert on Kelly Creek and Northwestern Railroad; aluminum tablet stamped "615"	612.
Ward, 900 feet east of station, 15 feet south of railroad, at edge of Kelly Creek, in large bowlder; aluminum tablet stamped "717"	714.

POINT 2.13 MILES WEST OF WRISTON, NORTH DOWN LOOP CREEK ALONG VIRGINIAN RAILWAY DEEPWATER.[a]

Wriston, 2.13 miles west of, 2.82 miles east of Kincaid, 800 feet east of milepost "DW 12," nearly opposite residence of Mr. Kincaid, on top step of south end of small stone culvert, chiseled square; marked "1289"	1,288.
Kincaid, 0.97 mile south of, 8 feet west of Virginian Railway, on outside of long curve, 100 feet west of Loop Creek, in sharp bend, 500 feet south of milepost "DW 10," in sandstone outcrop; aluminum tablet stamped "1184"	1,183. 7
Kincaid, opposite and 200 feet west of post-office, 1,200 feet south of mouth of Lick Branch; on top stone of east corner of north abutment of railroad bridge, chiseled square; marked "1137"	1,136. 6
Page, 1.26 miles north of post-office, 8 feet west of Virginian Railway, 250 feet south of milepost "DW 7," opposite coal hollow and town of North Page, in sandstone outcrop; aluminum tablet stamped "1065"	1,064. 1

[a] Other elevations near Robson will be found in list for Fayetteville quadrangle.

	Feet.
Robson, 3.33 miles north of, 500 feet north of point opposite mouth of Big Right Fork, 60 feet north of milepost "DW-2," on east corner of south bridge seat of double-span triple I-beam bridge 4, chiseled square; marked "769"	768.65
Robson, 4.03 miles north of (0.88 mile south of Deepwater post-office), 200 feet south of point opposite mouth of Little Right Fork, 2,000 feet south of milepost "DW-1," in west corner of north bridge seat of railroad bridge 1 across Loop Creek; aluminum tablet stamped "715"	714.134
Deepwater, at railroad crossing; top of rail; marked "651"	649.9
Deepwater, 1,000 feet east of post-office, 30 feet north of Chesapeake and Ohio Railway tracks, on sandstone bowlder; chiseled square; marked "647"	646.38

BALD KNOB, CHARLESTON SPECIAL, GILBERT, LOGAN, MADISON, OCEANA SPECIAL, PEYTONA AND ST. ALBANS 15′ (CHARLESTON AND OCEANA 30′) QUADRANGLES.

BOONE, KANAWHA, LINCOLN, MASON, McDOWELL, MINGO, PUTNAM, AND WYOMING COUNTIES.

The elevations in the following list are based upon corrected levels of the Great Kanawha River survey of the army engineers, checked by primary leveling from the Ohio River survey precise-level line. Some of the descriptions were previously published under Charleston and Oceana (30′) quadrangles. The elevations now given are 3.855 feet greater than by the datum of the old Great Kanawha River levels. The work is now subdivided into 15′ quadrangles.

Leveling was done in each quadrangle in 1896 and 1897 by Hargraves Wood; additional elevations were established in 1907 in the Charleston Special by R. A. Kiger, and in 1908 in the Peytona and Madison quadrangles by E. S. Dawson.

The elevations stamped on the standard bench marks set in 1897 and 1908 are mostly 1 foot too high, while the elevations stamped on those set in 1896 and 1907 are generally correct.

CHARLESTON SPECIAL (CHARLESTON 30′) QUADRANGLE.

POINT 1.03 MILES WEST OF DANA, EAST TO POINT 1.3 MILES NORTHEAST OF COAL FORK STATION ON CAMPBELL CREEK RAILROAD.

	Feet.
Coal Fork, 1.3 miles northeast of station, 10 feet west of track at west end of cut, in sandstone; aluminum tablet stamped "637"	636.726

MOUND, EAST TO CHARLESTON; THENCE NORTH TO WALLACE ON TUPPER CREEK.

Mound (Lock 6 on Kanawha River); top of coping stone (elevation by the Engineer Corps, 565.5)	569.355
Charleston, 2.75 miles northwest of, on sandstone from north wall of stone-arch bridge over Twomile Creek, known as Twomile Bridge; chiseled cross in square	596.10
Charleston, 1.25 miles northwest of state capitol, on sandstone wall at southeast corner of stone-arch bridge, 0.5 mile northwest of suspension bridge across Elk River; chiseled cross in square	593.70

	Feet.
Charleston, in southwest corner of state capitol; bronze tablet stamped "602–C"	600.703
Patrick, 3 miles north of, 200 feet southwest of Methodist Church known as Wesley Chapel, on Twomile Creek; copper bolt in bowlder; stamped "604–C"	603.826
Wallace, 0.75 mile east of store (8 miles north of Patrick), on south edge of road, 600 feet east of James Wallace's house, in bowlder; copper bolt stamped "668–C"	666.752
Rocky Fork, 3 miles north of, south side of Martin Branch, 0.25 mile above mouth, 175 feet west of first crossing near schoolhouse, in rock ledge 1 foot above grade; copper bolt stamped "592–C"	591.017

MOUND, NORTH TO TYLER CREEK SCHOOLHOUSE.

Mound, 2 miles northwest of, 0.25 mile southeast of forks of road near Tyler schoolhouse, in rock 20 feet west of drain; copper bolt stamped "623–C"	623.371

MOUND, SOUTH UP MIDDLE FORK OF DAVIS CREEK, TO MOUTH OF LONG BRANCH.

Ruth, 2 miles east of, on west side of Middle Fork of Davis Creek, 900 feet north of mouth of Long Branch, between third and second crossings north of schoolhouse, in large bowlder near Davis Creek; copper bolt stamped "C–659"	659.262

MARMET, SOUTH TO BROWNSTOWN.

Lock 5 (near Marmet); coping (U. S. Engineer Corps elevation, 572.50)	576.355
Rush Creek, 0.75 mile northwest of Chesapeake and Ohio Railway culvert over, in middle one of three ledges of rock west side Right Fork Rush Creek; copper bolt stamped "639–C"	638.943

ST. ALBANS 15′ (CHARLESTON 30′) QUADRANGLE.

POCA, SOUTH ALONG KANAWHA AND MICHIGAN RAILWAY, TO ST. ALBANS.

Poca station, 300 feet south of, in west side of south abutment of highway bridge over Correly Branch; copper bolt stamped "572–C"	572.341
Lock 7; top of coping (U. S. Engineer Corps elevation, 555.50)	559.355
St. Albans, fence line on west side of First street, 60 feet north of north rail of Chesapeake and Ohio Railway track, in center of west base of monument, top of limestone post projecting 1 foot above ground; copper bolt (Coast and Geodetic Survey elevation, 594.78)	594.691

ST. ALBANS, NORTHWEST ALONG CHESAPEAKE AND OHIO RAILWAY, TO SCOTT STATION.

St. Albans, in front of station; top of rail	596.4
Scott, 75 feet south of station, in Pine's orchard, 50 feet south of Chesapeake and Ohio Railway tracks; iron post stamped "693–C"	692.856

ST. ALBANS, WEST, VIA TACKETT CREEK, TO YOUNG'S STORE; THENCE SOUTH TO GARRETTS BEND, THENCE NORTHEAST TO ST. ALBANS.

St. Albans, 5 miles west of, south of road, first house south of Young's store, belonging to John Hodges, in east chimney 6 feet from ground; copper bolt stamped "U. S. G. S.–737"	737.294
Garretts Bend, 2 miles north of, Trace Fork of Mud River, 200 feet below mouth of Twomile Branch, 400 feet northwest of Anderson McAllister's house, north side of stream, in huge rock; copper bolt stamped "U. S. G. S.–669"	669.125
Tornado, 1.5 miles southwest of, on road up Falls Creek, on south side of road 150 feet above the first crossing of Falls Creek; iron post stamped "614"	613.708

PEYTONA 15′ (CHARLESTON 30′) QUADRANGLE.

POINT 3 MILES UP COAL FORK OF CABIN CREEK, WEST VIA COAL RIVER AND LAUREL CREEK, TO MOUTH OF ROBINSON CREEK, 1.5 MILES EAST OF UNEEDA.

	Feet.
Ohley, 4.7 miles southwest of, north of road, opposite house, 400 feet northwest of house and hollow, near bend in creek, on rock cliff, chiseled square; painted "983"	981.74
Orange, 3.4 miles east of, south of road, 265 feet north of ridge road and along road up mountain, 0.3 mile east of schoolhouse, in large rock; aluminum tablet stamped "1633"	1,632.017
Orange, 2.5 miles east of, north of road, 80 feet west of road fork top of mountain, on sandstone outcrop, chiseled square; painted "1563"	1,562.47
Orange, 1 mile east of, east of road and run, on top of small summit, 0.3 mile west of mountain foot, on outcrop of sand rock, chiseled square; painted "940"	939.60
Orange, 0.5 mile north of post-office, south side of Whiteoak Creek, 300 feet west of mouth of Little Whiteoak Creek, 0.2 mile east of mouth of Whiteoak Creek, in rock cliff; aluminum tablet stamped "734"	732.963
Orange, 3.2 miles west of, north edge of road, 150 feet west of small hill, 400 feet east of schoolhouse 13, opposite Horse Hollow, in rock cliff; aluminum tablet stamped "735"	733.697
Orange, 5 miles west of, 20 feet west of road, at bend of river where road comes back to river, on large bowlder, chiseled square; painted "691".	690.30
Seth post-office, 0.3 mile southeast of, north of road, in bank in front of Laurel Church, opposite mouth of Laurel Creek, 0.1 mile northwest of schoolhouse, in outcrop of rock; aluminum tablet stamped "715"	714.252
Seth, 1.5 miles south of, east of road, west of Laurel Run, opposite hollow, 220 feet east of second house up Laurel Creek, on outcrop of sandstone, chiseled square; painted "689"	688.57
Nelson, 200 feet southeast of mouth of Hopkins Fork on Laurel Creek, in face of rock cliff; bronze tablet stamped "734-C"	734.388
Nelson, 300 feet northwest of post-office, west of Laurel Creek, 40 feet west of road, 40 feet south of foot log, 370 feet south of road fork and opposite hollow, in outcrop of rock in bank; aluminum tablet stamped "732"	731.072
Nelson, 2 miles south of, east of log railroad and county road, 0.8 mile south of schoolhouse, 3 feet from ground, in face of rock cliff; aluminum tablet stamped "863"	862.283
Nelson, 3.9 miles southwest of, north of railroad, on Laurel Creek, opposite hollow, 0.2 mile west of Skidway, on rock cliff; chiseled square	919.26
Nelson, 5.7 miles southwest of, south of Laurel Creek, 300 feet from foot of mountain, 300 feet from house, 5 feet from barn, in bowlder in bank; aluminum tablet stamped "1089"	1,087.884
Uneeda, 3.3 miles southeast of, north of Robinson Creek, at mouth of hollow, north of house, on outcrop of rock, chiseled square; painted "858".	857.07

BROWNSTOWN, SOUTHWEST, ALONG LENS AND SHORT CREEKS, TO RACINE; THENCE NORTHWEST, DOWN COAL RIVER, TO COBBS.

Hernshaw, 1 mile south of, south side of road, on south bank of Lens Creek, near A. Hoffman's house, in 3- by 5-foot ledge rock; copper bolt stamped "722-C"	722.185
Peytona, 2 miles northwest of, south side of road down Coal River, 100 feet northwest of Laurel Branch, 1 mile below Whiteoak Branch, in ledge of rock; copper bolt stamped "665-C"	665.401
Cobbs, 200 feet north of mouth of Lick Creek, west side of Coal River road, in rock; copper bolt stamped "648-C"	648.375

RACINE, SOUTHEAST TO COMFORT; THENCE SOUTHWEST TO NELSON.

	Feet.
Comfort, 0.12 mile north of, 0.5 mile south of mouth of Joes Creek, east of Coal River road, 4 feet above grade, in bottom of rock cliff; copper bolt stamped "673–C"	673.488

MADISON 15′ (CHARLESTON 30′) QUADRANGLE.

ROBINSON CREEK, WEST VIA POND FORK, LITTLE COAL RIVER, PETERS CAVE FORK, AND SULPHUR SPRING FORK, TO GRIFFITHSVILLE.

Uneeda, 1.4 miles southeast of, 40 feet north of road, 700 feet east of house, 700 feet east of mouth of Robinson Creek, and back of barn, in outcrop of rock in field; aluminum tablet stamped "751"	750.135
Uneeda, 0.5 mile southeast of post-office, south of road, north of Pond Fork, along narrows, 0.1 mile northeast of hollow, in large rock bowlder; aluminum tablet stamped "723"	722.334
Uneeda, 0.8 mile west of post-office, south of road, north of Pond Fork, 400 feet east of schoolhouse, along narrows, on outcrop of rock, chiseled square; painted "718"	717.29
Madison, 2 miles southeast of, west of Pond Fork, 220 feet west of road, 0.2 mile south of bend in run, 0.2 mile north of hollow, in rock cliff; aluminum tablet stamped "697"	696.068
Madison, in west side of foundation of Boone county jail; aluminum tablet stamped "704"	703.221
Madison, 1.1 miles west of post-office, southeast of railroad, 500 feet southwest of milepost 1, on sandstone outcrop; chiseled square	693.12
Danville, 0.5 mile west of post-office, 300 feet west of brickyard, 10 feet west of county road, 10 feet south of railroad, on south abutment of culvert at mouth of John Hill Branch, chiseled square; painted "686"	684.50
Danville, 1.5 miles west of, 90 feet west of Hopkins station, 500 feet north of milepost 3, between house and railroad, in east end of foundation of Mr. Hopkins's cellar; aluminum tablet stamped "679"	677.402
Danville, 4.5 miles northwest of, west of railroad, 300 feet west of county road, between houses, in west abutment of culvert; aluminum tablet stamped "666"	664.384
Danville, 6.5 miles northwest of, east of railroad, 0.2 mile northwest of milepost 8, on rock cliff; chiseled square; painted "669"	668.03
Hill, 600 feet west of post-office, south of railroad, 200 feet west of trestle, 600 feet from road crossing and station, in rock cliff; aluminum tablet stamped "667"	665.404
Hill, 2 miles northwest of, west of road, near small summit, 500 feet east of house, on sandstone outcrop, chiseled square; painted "658"	657.27
Woodville, 300 feet east of post-office (3 miles west of Hill post-office), 170 feet north of mouth of Laurel Fork, west of road, in bowlder; copper bolt stamped "673"	672.622
Woodville, 2.4 miles west of, 600 feet north of Sulphur Spring Fork at its mouth, east of road and run, in top of bowlder; aluminum tablet stamped "772"	770.923
Woodville, 3.3 miles northwest of, north of road, 600 feet north of Gum Run, on rock, chiseled square; painted "831"	829.65
Woodville, 4.2 miles northwest of, north of road, on top of mountain, on rock, chiseled square; painted "1063"	1,061.82
Woodville, 5.8 miles northwest of, opposite sawmill, 40 feet off road in field, opposite hollow, 300 feet west of house, in outcrop of rock; aluminum tablet stamped "826"	824.747

	Feet.
Woodville, 7.4 miles northwest of, north of Sugartree Fork, north of road, 300 feet east of house, on outcrop of rock, chiseled square; painted "706"	704.66
Woodville, 9.1 miles northwest of, at foot of hill, west of road, north of run, on small rock, chiseled square; painted "671"	670.39

GARRETTS BEND, SOUTH VIA SAND GAP, SUGARCAMP KNOB, AND HILL POST-OFFICE, TO MADISON.

Sand Gap, 500 feet west of forks of road, in huge rock above John A. Midkiff's house; copper bolt stamped "U. S. G. S.–1079"	1,078.545
Hill, 3 miles west of, 200 feet above confluence of Laurel Fork and Horse Creek, opposite James McClure's house near last crossing of Laurel, on east bank, in rock ledge; copper bolt stamped "U. S. G. S.–673"	672.622
Hill, 2 miles north of post-office, 1 mile above mouth of Trace Branch, on left side of right-hand hollow on Trace Branch of Horse Creek; copper bolt stamped "U. S. G. S.–766"	765.931
Hill, 3 miles southeast of, 0.25 mile north of Camp Creek, on east side of road up Little Coal River, 300 feet above B. Stolling's, in small ledge of rock; copper bolt stamped "U. S. G. S.–660"	660.170

SINGLE SPUR LINE UP LICK CREEK.

Danville, 4 miles west of, on right fork of Lick Creek, 25 feet east of creek, between two walnut trees, one of which is blazed, in bowlder above coal bank; copper bolt stamped "U. S. G. S.–820"	819.403

LOGAN 15′ (OCEANA 30′) QUADRANGLE.

MADISON, SOUTH UP SPRUCE FORK, TO SENG POST-OFFICE (PARTLY SINGLE SPUR LINE).

Seng, 2 miles northwest of, 0.12 mile above mouth of Beach Creek on north side of Spruce Fork, 300 feet below splash dam, opposite William Coleman's barn, in ledge of rock; copper bolt stamped "U. S. G. S.–846"	845.309

HEWETT, SOUTHWEST TO PECK; THENCE UP GUYANDOT RIVER TO MAN.

Hewett, 300 feet above mouth of Hewett Creek, opposite schoolhouse on south side of creek, in ledge of rock; copper bolt stamped "U. S. G. S.–767"	767.029
Pecks Mill, 0.25 mile south of post-office, on northwest side of Mill Creek, 300 feet above mouth, in northwest corner of huge bowlder; copper bolt stamped "U. S. G. S.–653"	652.624
Logan, in northeast corner of court-house wall; bronze tablet stamped "678"	677.897
Man, 5 miles northwest of, opposite mouth of Rich Creek, 20 feet north of Methodist Episcopal Church, in rock; copper bolt stamped "U. S. G. S.–725"	724.634
George McDonald's field, 1,500 feet below his house, on south side of Guyandot River, in root of cedar tree; nail (bench mark of Norfolk and Western Railroad, elevation 724.465)	730.052

MAN, NORTHEAST UP BUFFALO CREEK (SINGLE SPUR LINE).

Man, 2.5 miles northeast of, west side of Buffalo Creek, 3 miles above mouth of Buffalo Creek; copper bolt stamped "U. S. G. S.–808"	807.614

GILBERT 15′ (OCEANA 30′) QUADRANGLE.

MAN, NORTHEAST UP BUFFALO CREEK (SINGLE SPUR LINE).

Man, 0.25 mile above mouth of Buffalo Creek, opposite Martin Dose's, 60 feet above foot log, west side of Buffalo Creek, in rock; copper bolt stamped "U. S. G. S.–728"	727.586

MAN, SOUTHWEST UP ROCKHOUSE BRANCH (SINGLE SPUR LINE).

	Feet.
Man, 2 miles southwest of, 1 mile above mouth of Rockhouse Branch, on west side, in rock near south end of cliff; copper bolt stamped "U. S. G. S.–792"	791.824
Man, 1 mile south of, 300 feet above mouth of Big Huff Creek, on east side, in rock; copper bolt stamped "U. S. G. S.–727"	727.037

MAN, SOUTH VIA GILBERT, TO WHARNCLIFFE.[a]

Gilbert, opposite Alexander Stafford's store, in field; iron post stamped "832"	831.646
Wharncliffe, 4 miles north of, on Ben Creek, 300 feet below Laurel Branch, east of road, opposite T. E. Brown's house; iron post stamped "1020"	1,019.815

BENCH MARKS AT WHARNCLIFFE RECOVERED BY LEVELING OF 1909.

Wharncliffe, railroad bridge over Ben Creek, bridge seat of east abutment (bench mark of Norfolk and Western Railroad, elevation 820.39)	823.52
Wharncliffe, 0.5 mile south of, at corner of state lines (Ky.–Va.–W. Va.); iron post stamped "825"	826.697

WHARNCLIFFE, SOUTHEAST UP BIG SANDY RIVER AND LONG POLE CREEK (SINGLE SPUR LINE.)

Dotson, 4 miles east of, on Long Pole Creek, 1,200 feet below Oak Branch, south of road; iron post stamped "1050"	1,051.819

MAN, EAST UP BIG HUFF CREEK, TO CYCLONE.

Cyclone, opposite Henchman's house, in rock; copper bolt stamped "U. S. G. S.–854"	853.992

OCEANA SPECIAL (OCEANA 30′) QUADRANGLE.

CYCLONE, EAST UP BIG HUFF CREEK AND TONEY FORK.

Cyclone, 7 miles east of, south side of Toney Fork of Big Huff Creek, about 2 miles above mouth, in ledge of rock; copper bolt stamped "U. S. G. S.–1234"	1,234.489

MOUTH OF TONEY FORK, EAST AND NORTHEAST UP BIG HUFF CREEK, TO ECHART.

Cyclone, 6 miles east of, 600 feet below Lower Gap Branch, east of road up Big Huff Creek, 100 feet above D. H. Cook's store; iron post stamped "1068"	1,067.600

BALD KNOB 15′ (OCEANA 30′) QUADRANGLE.

ECHART, NORTH DOWN POND FORK OF LITTLE COAL RIVER, VIA BALD KNOB AND CROOK, TO MOUTH OF ROBINSON CREEK.

Echart, east bank of Pond Fork of Little Coal River, opposite mouth of Skin Fork, in ledge of rock; copper bolt stamped "U. S. G. S.–1423"	1,422.020
Bald Knob, east side of valley opposite Eddy Workman's, in bowlder; copper bolt stamped "U. S. G. S.–1101"	1,101.060
Bald Knob, 3.5 miles northwest of, north side of Cow Creek, 0.75 mile from mouth of Cow Creek, 800 feet from James Gunnoe's, in ledge of rock; copper bolt stamped "U. S. G. S.–1039"	1,039.100

GORDON, EAST UP WEST FORK, TO BROWNS BRANCH (SINGLE SPUR LINE).

Gordon, north side of West Fork, 1,000 feet east of junction of West Fork and Pond Fork to form Little Coal River, in rock; copper bolt stamped "U. S. G. S.–808"	809.014
Gordon, 2.5 miles east of, on West Fork, 800 feet below Browns Branch, west of road a little above and nearly opposite small water mill, in ledge of rock; copper bolt stamped "U. S. G. S.–884"	884.330

[a] An unadjusted single line closing 1.54 feet low on adjusted elevation at Wharncliffe.

STEUBENVILLE AND WELLSVILLE QUADRANGLES.

BROOKE AND HANCOCK COUNTIES.

Leveling in Wellsville quadrangle in 1902 by A. T. Bagley and in Steubenville quadrangle in 1902 by J. A. Buford.

WELLSVILLE QUADRANGLE.

EAST LIVERPOOL, OHIO, SOUTH TO FAIRVIEW.

	Feet.
Chester, 2 miles south of, 0.25 mile east of Locust Grove Cemetery, Allison triangulation station; bronze tablet in top of marble post, stamped "1337 STBNVL"	1,337.156

NEW CUMBERLAND, NORTHEAST ALONG ROAD TO FAIRVIEW, THENCE EAST TO KENDALL, PA.

Fairview, on the north side of Tri-State Normal School, at base of stone frame to front door; aluminum tablet stamped "1196 STBNVL"	1,195.638

STEUBENVILLE QUADRANGLE.

WELLSBURG, NORTH TO CROSS CREEK, THENCE EAST UP SAME ABOUT 5 MILES; THENCE NORTH TO COLLIERS; THENCE NORTHWEST TO HOLLIDAYS COVE; THENCE SOUTHWEST TO STEUBENVILLE, OHIO.

Rockdale, 0.2 mile west of, southeast corner of bridge over Cross Creek, opposite Wabash concrete bridge, in stone abutment; chiseled cross	672.400
Colliers Station, at northwest corner of bridge, in stone abutment, aluminum tablet stamped "824 STBNVL"	823.597
Hollidays Cove, 0.5 mile east of, Pittsburg, Cincinnati, Chicago and St. Louis Railway bridge 39, in coping stone at southwest corner; chiseled square	741.90

HOLLIDAYS COVE, NORTH TO NEW CUMBERLAND.

Zalia (Penrith), 100 feet south of church, on east side of road, opposite lower end of Toronto street at Ferry, in big bowlder; bronze tablet stamped "704 STBNVL"	703.720
New Cumberland, southwest corner of D. S. Schiller Foundry Company's works, Front and Ferry streets, in west end of door stoop; chiseled square (U. S. Engineer Corps bench mark 56 A)	670.66

NEW CUMBERLAND, EAST TO COMETTSBURG, PA.; THENCE SOUTHWEST TO HOLLIDAYS COVE.

New Cumberland, 3.25 miles east of; at northeast corner of bridge; T cut in stone	935.14

SCHOOLHOUSE ON CROSS CREEK, SOUTHEAST TO INDEPENDENCE, PA.; THENCE WEST TO WELLSBURG.

Rockdale, 2.5 miles east of; at schoolhouse, covered bridge on Parmar Run near junction with Cross Creek, in southwest corner of abutment; chiseled cross	754.35
Wellsburg, 1 mile east of; stone horse block in front of Jacob's house; aluminum tablet stamped "1001 STBNVL"	1,000.935

CAMERON, NEW MARTINSVILLE, AND WHEELING QUADRANGLES.

BROOKE, MARSHALL, OHIO, TYLER, AND WETZEL COUNTIES.

Leveling in Wheeling quadrangle in 1901 by W. A. Freret, jr.; in Cameron quadrangle in 1902 by G. L. Gordon; and in New Martinsville quadrangle in 1903 by R. E. McFadden, and in 1904 by G. L. Gordon.

WHEELING QUADRANGLE.

WHEELING, EAST ALONG NATIONAL PIKE VIA ELM GROVE, TO TRIADELPHIA.

	Feet.
Wheeling, north front of city building, 37 feet east of northwest corner; chiseled square (U. S. Engineer Corps bench mark 90–A)	678.25
Wheeling, 1.1 miles east of post-office, Baker Street Bridge on Wheeling Creek, on southwest corner of coping stone at southeast end of bridge; chisel mark	651.23
Elm Grove, 1 mile southeast of, bridge over Little Wheeling Creek near its junction with Wheeling Creek, on top of west coping wall, in third stone from center; cut	694.75
Triadelphia, M. E. Church brick building, in foundation stone of south face at southwest corner; aluminum tablet stamped "745 GRAFTON"	744.57

TRIADELPHIA, SOUTHEAST ALONG HIGHWAYS, UP MIDDLE WHEELING CREEK AND NORTH TO VALLEY GROVE.

Twilight, 0.6 mile west of, northeast abutment of bridge over Wagners Run, northeast corner of stone; chisel mark	802.03
Twilight, 3.1 miles northeast of, near junction of Hancytown pike and Middle Wheeling Creek road, bridge over Middle Wheeling Creek, northeast wing retaining wall, corner of fourth stone from top; chisel mark	949.79
Valley Grove, Baltimore and Ohio Railroad (Pittsburg division), bridge 174, in north face of south pier; bronze tablet stamped "953 GRAFTON"	952.64

VALLEY GROVE, ALONG NATIONAL PIKE AND NORTH UP M'GRAW RUN, TO BETHANY.

Bethany, 5.1 miles south of, southeast abutment wall of wooden bridge over Longs Run, on southeast corner of third stone from top; chisel mark	1,020.87
Bethany, 2 miles south of, at northeast corner of M. E. Church, on top stone at southeast stone step; chisel mark	954.32
Bethany, 0.3 mile west of, in front face of Bethany College, north side of first entrance west of main entrance, east face of stone water table; aluminum tablet stamped "932 GRAFTON 1901"	931.77

BETHANY, ALONG PIKE, TO SHORT CREEK.

Bethany, 2.6 miles west of, west end of bridge over Buffalo Creek, on northeast corner of top stone of north wing wall; chisel mark	743.82
Short Creek, brick store and post-office, in west face, 25 feet from southwest corner and 2 feet above ground; aluminum tablet stamped "668 GRAFTON 1901"	667.96
Short Creek, 0.1 mile south of, west side of railroad track, Pittsburgh, Cincinnati, Chicago and St. Louis Railway bridge 12 over Short Creek, on top of south abutment; chiseled square, marked "U. S. B. M.□" (U. S. Engineer Corps bench mark 81 A)	652.72

CAMERON QUADRANGLE.

MOUNDSVILLE, EAST ALONG PUBLIC ROADS, VIA LIMESTONE AND BEULA STATION, TO ROCKLICK.

Moundsville, Marshall County court-house, in front of building, 17.2 feet east of center of doorway; on top of water table of foundation (U. S. Engineer Corps bench mark 101–B)	690.51
Limestone, brick dwelling of R. H. Peters, in top stone of foundation of front, 2.7 feet northwest of center of door; bronze tablet stamped "1377 GRAFTON"	1,376.78
Pleasant Valley, 0.4 mile southeast of, brick dwelling of J. W. Cunningham, on top of stone at front gate; chiseled square	1,317.05
Beelers Station, on northeast corner of first step above stone platform; chiseled square	1,356.54

ROCKLICK, SOUTH ALONG PUBLIC ROADS AND BALTIMORE AND OHIO RAILROAD, VIA CAMERON AND WOODRUFF, TO BELLTON.

	Feet.
Rocklick, 0.3 mile south of, south side of southeast corner of schoolhouse, in second stone; aluminum tablet stamped "1464 GRAFTON"	1,463.805
Cameron, 1.8 miles northeast of, M. E. Church at northeast angle of cross-roads, on top at south end of retaining wall; chiseled square	1,074.79
Cameron, west end of brick public school building, 0.9 foot north of south-west corner in water table; bronze tablet stamped "1170 GRAFTON"	1,169.864
Woodruff, 0.7 mile northwest of, west end of stone culvert, center of top; chiseled square	1,015.98
Bellton, 0.1 mile north of, in southeast corner of north abutment of railroad bridge 136, 2.7 feet above bridge seat; bronze tablet stamped "888 GRAFTON"	887.579

BELLTON, WEST ALONG PUBLIC ROADS, VIA ADALINE, TO LYNN CAMP.

Kausooth post-office, 2.4 miles west of, on top of west abutment of bridge over Big Run, 12.5 feet right of center of bridge; chiseled square	768.40

LYNN CAMP, NORTHWEST ALONG PUBLIC ROADS AND BALTIMORE AND OHIO RAILROAD, VIA MEIGHEN AND ROSBYS ROCK, TO MOUNDSVILLE.

Meighen, at schoolhouse No. 5, east side, 8 feet from southeast corner, in top stone of foundation; bronze tablet stamped "691 GRAFTON"	690.667
Rosbys Rock, northeast abutment of iron bridge over Grave Creek, 12 feet southeast of center of bridge, 1 foot below bridge seat; bronze tablet stamped "779 GRAFTON"	778.326
Rosbys Rock, 4 miles northwest of, on top of northwest corner of south abutment of railroad bridge 146 over Grave Creek; chiseled square	680.75
Moundsville, Marshall County court-house, south front of, 17.2 feet east of center of doorway; bronze tablet stamped "690 GRAFTON"	689.284

LONE OAK SCHOOLHOUSE, NORTH ALONG PUBLIC ROADS TO HAZELDELL, SCHOOLHOUSE (SINGLE SPUR LINE).

Hazeldell or Irish Ridge schoolhouse, center of southwest corner stone; bronze tablet stamped "1322 GRAFTON"	1,321.542

NEW MARTINSVILLE QUADRANGLE.

PROCTOR, SOUTHEAST ALONG HIGHWAYS, TO HALLS MILLS.

Proctor, Baltimore and Ohio Railroad bridge 317 over Proctor Creek, in west end south abutment; bronze tablet stamped "632 GRAFTON 1902"	632.114
Marion, 0.2 mile east of post-office, opposite Marion Moore's store building, south of creek, on stone; chiseled square	881.62

NEW MARTINSVILLE, SOUTHWEST ALONG EAST SIDE OF OHIO RIVER, TO SISTERSVILLE; THENCE SOUTHEAST TO MIDDLEBOURNE.

New Martinsville, in county court-house, facing Main street, near Main street entrance; bronze tablet stamped "630 GRAFTON 1903"	630.282
Lively crossing; top of rail at flag station	630
Mendota; top of rail at flag station	628.1
Paden, in front of station; top of rail	630
Stewarts crossing, in front of station; top of rail	633
Sistersville, in city hall, in sill on south side; bronze tablet stamped "649 STBNVL"	648.606
Luzon, iron bridge over Pursley Creek, at foot of hill, on top stone of south-east foundation; circle	736.97
Luzon, 0.5 mile southeast of, east side of road, opposite Kellar's old store building, on stone; square	1,055.41

	Feet.
Luzon, 2.5 miles southeast of, on northeast abutment of iron bridge over Point Pleasant Creek near where it empties into Middle Island Creek, on top stone; chiseled square	684.56

MIDDLEBOURNE, NORTHEAST ALONG HIGHWAY, TO POLARD; THENCE EAST TO CONAWAY; THENCE NORTHEAST TO READER; THENCE NORTHWEST, ALONG BALTIMORE AND OHIO RAILROAD (SHORT LINE), TO NEW MARTINSVILLE.

Polard, 0.5 mile northeast of post-office, on rock north of road near Elk Creek; chiseled square	745.46
Conaway, in southeast corner of James W. Mayfield's cellar, facing post-office; aluminum tablet stamped "840 GRAFTON 1903"	841.033
Reader, 2 miles northwest of, on southwest abutment of large railway bridge 121 over Fishing Creek; chiseled square	680.73
Flannagan, in front of flag station; top of rail	678
Reader, 3 miles northwest of, on southwest abutment of bridge 110, over Fishing Creek; chiseled square	676
Porter Falls, 0.6 mile northwest of, on southeast abutment of small bridge; chiseled square	670.64
Minnie, in front of flag station; top of rail	647.2
Minnie, 360 feet west of flag station, on southwest abutment of railway bridge 74; chiseled square	646.28
Bard, in front of telegraph office; top of rail	641.2
Minnie, 6 miles northwest of, on north end of small railway culvert over Bank Run; chiseled square	621.24

BELLEVILLE, MARIETTA, PARKERSBURG, AND ST. MARYS QUADRANGLES.

JACKSON, PLEASANTS, RITCHIE, AND WOOD COUNTIES.

Leveling in St. Marys quadrangle in 1903 by R. E. McFadden, and in 1904 by G. L. Gordon; in Marietta and Parkersburg quadrangles in 1902, and in Belleville quadrangle in 1903, by J. W. Hodges.

ST. MARYS QUADRANGLE.

LITTLE, SOUTHWEST ALONG HIGHWAY, TO UNION MILLS; THENCE SOUTH TO ELLENBORO.

	Feet.
Arvilla, in south end of east abutment of iron bridge over Middle Island Creek; bronze tablet stamped "634 ADJ 1904"	634.482
Union Mills, 0.4 mile southeast of mouth of McKim Creek, 100 feet north of Charles Little's blacksmith shop, in top of north end of east abutment of iron bridge; bronze tablet stamped "614 GRAFTON 1903"	614.877
Adlai, 135 feet east of road, 75 feet south of J. H. Fleming's house, in rock; bronze tablet stamped "777 GRAFTON 1903"	777.320

TUNNEL 9, WEST ALONG BALTIMORE AND OHIO RAILROAD, TO TUNNEL 10.

Ellenboro, 1.8 miles east of, on south end of east abutment of railroad bridge 27; chiseled square	807.70
Ellenboro, road crossing at station; top of rail	784
Ellenboro, 150 feet west of station, in east abutment of south end of bridge over small stream from north; bronze tablet stamped "780 GRAFTON 1903"	780.135
Tunnel 10, 1 mile east of, on top of stone, south end east abutment of bridge 28; chiseled square	760.67

RAVENROCK, SOUTHWEST ALONG OHIO RIVER RAILROAD, TO FRENCH CREEK.

	Feet.
Ravenrock, 200 feet southeast of station, northeast side of large rock above a spring; aluminum tablet stamped "647 ADJ 1903"	646.981
Ravenrock, in front of station; top of rail	623.2
Spring Run, in front of station; top of rail	621.4
Grape Island, railroad crossing at station; top of rail	621.8
St. Marys, 0.76 mile northeast of, on southeast end of southwest abutment of railroad bridge over Middle Island Creek; chiseled square	621.17
St. Marys, corner of Second and Washington streets, First National Bank Building, facing Second street, 1.1 feet from southwest corner of building and 4.5 feet above street; aluminum tablet stamped "628 ADJ 1903"	628.097
St. Marys, on water table of post-office building, south of entrance facing Main street; chiseled square	624.29
Vaucluse, in front of station; top of rail	626

UNION MILLS, WEST ALONG HIGHWAYS, TO ST. MARYS.

Union Mills, 2.05 miles west of, on north end pier of iron bridge over Willow Island Creek; chiseled square	610.87
Union Mills, 3.6 miles west of (1.7 miles east of St. Marys), in north end of east abutment of iron bridge over Broad Run; bronze tablet stamped "608 ADJ 1903"	608.185

NUTTERS FARM, NORTH ALONG HIGHWAY 6 MILES TO MOUTH OF DOUGLAS RUN (CHECKED SPUR LINE).

Goose Creek, 3 miles southwest of, 3 miles north of Nutters Farm, northwest side of road and Goose Creek, in shelf in rock outcrop; bronze tablet stamped "761 ADJ 1903"	760.970
Goose Creek, 0.4 mile west of, southeast bank of Goose Creek, 0.2 mile northeast of junction of road down Douglas Run and 320 feet southeast of road, in face of rocky cliff; bronze tablet stamped "808 ADJ 1903"	807.872

PARKERSBURG QUADRANGLE.

PARKERSBURG, EAST ALONG HIGHWAY, TO TALLYHO.

Parkersburg, corner of Fifth and Julian streets, at southeast corner of custom-house and post-office, on top of foundation water table; chiseled square marked U.S.□B.M. (U. S. Engineer Corps bench mark 183-A)	615.806
Parkersburg, custom-house and post-office, on south side near west end in water table; bronze tablet stamped "616 GRAFTON 1902"	615.231
Parkersburg, 3.2 miles east of, on south side of pike, on south foundation of small bridge; chiseled square	602.43

POHICK, SOUTH ALONG OHIO RIVER RAILROAD, TO PARKERSBURG.

Kellar, in front of station; top of rail	613
Briscoe station, opposite highway to post-office, in face of rock ledge facing Ohio River; bronze tablet stamped "594 GRAFTON 1902"	593.662

MARIETTA QUADRANGLE.

TALLYHO, EAST ALONG HIGHWAY TO DEERWALK; THENCE NORTH TO WILLOW; THENCE NORTHEAST ALONG RAILROAD TO FRENCH CREEK.

Tallyho, 1.5 miles southeast of, opposite Shiloh United Brethren Church, at forks of road, in large bowlder; aluminum tablet stamped "714 GRAFTON 1902"	713.560
Borland, 100 feet east of post-office, on south side of Bull Creek; bronze tablet stamped "683 GRAFTON 1902"	682.728
Belmont, 0.5 mile northeast of, on top of south abutment west end of railway bridge 66 over French Creek; chiseled square	614.28

WILLOW, WEST ALONG OHIO RIVER RAILROAD TO WILLIAMSTOWN; THENCE SOUTH ALONG SAME TO POHICK.

	Feet.
Willow Island station, in northeast corner of foundation wall of Jos. I. Norris's dwelling; aluminum tablet stamped "616 GRAFTON 1901"	615.448
Compton, in front of station; top of rail	615
Williamstown, in front of station; top of rail	610
Pohick, in front of station; top of rail	616

BELLEVILLE QUADRANGLE.

PARKERSBURG, SOUTH ALONG HIGHWAY, VIA NEWPORT AND MINERAL WELLS, TO ROCKPORT.

Mineral Wells, 1.2 miles southwest of, in face of abutment of small iron bridge over Badgley Fork, northwest end; aluminum tablet stamped "593 GRAFTON 1903"	593.409
Fountain Spring, north abutment of iron bridge over Tygart Creek, on top; chiseled square	622.34
Saulsbury, 1.2 miles south of, east of road, on northeast end of Valley Belle schoolhouse, on top of corner stone; chiseled square	653.76
Rockport, opposite schoolhouse No. 2, at forks of road, on top of large rock; aluminum tablet stamped "700 GRAFTON 1903"	700.497

ROCKPORT, WEST ALONG HIGHWAY, TO BELLEVILLE.

Sloan, 0.2 mile west of, on rock north of road; chiseled square	726.89
Oak, 0.8 mile west of, on stone of small culvert on north side of road; chiseled square	619.74
Belleville, 0.8 mile south of, 0.2 mile south of road crossing, in small ravine east of track, in top of rock; aluminum tablet stamped "595 GRAFTON 1903"	595.172
Pond Creek, 1,200 feet north of, on northwest corner of capstone of culvert (U. S. Engineer Corps bench mark 204–A)	599.227

AT NEW ENGLAND (SET FROM U. S. ENGINEER CORPS B. M. "195–A").

New England, 0.5 mile west of Baltimore and Ohio Railroad station, on west abutment of railroad culvert over Beadle Run, 7 feet north of south end of culvert, 1,200 feet above Mushapha Island, 23 feet west of center of railway, and .008 foot higher than adjoining army engineers' bench mark; aluminum tablet stamped "591 GRAFTON 1903"	590.712

ROCKPORT, SOUTH ALONG HIGHWAY, TO WISEBURG.

Rockport, 1 mile south of, on southwest abutment of small bridge over Tygart Creek, chiseled square	761.58
Rockport, 6 miles south of, on Sandy Creek, 240 feet north of old Wiseburg post-office, north side of road, in top of rock; aluminum tablet stamped "663 GRAFTON 1903"	662.901

GLENWOOD, KENO, POINT PLEASANT, AND RAVENSWOOD QUADRANGLES.

CABELL, JACKSON, MASON, AND PUTNAM COUNTIES.

Leveling in Keno quadrangle in 1904 by F. W. Hughes; and in Glenwood, Point Pleasant, and Ravenswood quadrangles in 1905, by G. L. Gordon.

KENO QUADRANGLE.

SET FROM U. S. ENGINEER CORPS BENCH MARK 211–A.

	Feet.
Brewster (formerly Williams), 450 feet north of station, in top of Baltimore and Ohio Railroad culvert over Williams Run, 28 feet west of center of track, 7 feet south of northwest corner of culvert; aluminum tablet stamped "589 ADJ 1903"	581.340

POINT PLEASANT QUADRANGLE.

GALLIPOLIS, OHIO, CROSSING BY RECIPROCAL READINGS, TO WEST VIRGINIA; THENCE NORTH ALONG RAILROAD TO WEST COLUMBIA.

	Feet.
Gallipolis Ferry, 1 mile south of Baltimore and Ohio Railroad station, in top at southwest corner of open culvert; aluminum tablet stamped "582 ADJ 1903"	581.765

POINT PLEASANT, NORTH ALONG BALTIMORE AND OHIO RAILROAD, TO WEST COLUMBIA; THENCE EAST ALONG PUBLIC HIGHWAY, TO LOCUST GROVE SCHOOLHOUSE.

Point Pleasant, highway on top of stone foundation northwest corner of Mason County court-house; chiseled square and letters U. S. B. M.) (army engineers' bench mark 264–A)	569.049
Point Pleasant, west side of "Cornstalk Monument" in Mason County court-house yard; bronze tablet stamped "570–A"	569.431
Point Pleasant, Lock 11, zero of gage	513.94
Linn (York station), Mr. Hoggs's brick house, at northwest corner of top stone of foundation, northwest face; bronze tablet stamped "586 ADJ 1903"	586.084
Maggie, railroad bridge over small run, west end of south abutment; bronze tablet stamped "569 ADJ 1903"	568.734
Spilman, 0.2 mile east of, south of track, in south face of outcrop of rock; bronze tablet stamped "576 ADJ 1903"	576.008
West Columbia, 2.4 miles east of, on left side of Tenmile Creek, opposite Locust Grove schoolhouse, in shelf of rock cliff; bronze tablet stamped "603 ADJ 1903"	603.406

DEBBY, NORTHWEST, ALONG KANAWHA AND MICHIGAN RAILROAD, TO POINT PLEASANT.

Ambrosia, road crossing; top of rail	566.6
Ambrosia, 0.1 mile north of, east of road, 30 feet south of end of covered bridge over Rockcastle Creek, in shelf of rock; bronze tablet stamped "577 ADJ 1903"	576.792
Ambrosia, 2.5 miles northwest of, iron bridge over Threemile Creek, southeast pier, south corner of bridge seat; bronze tablet stamped "554 ADJ 1903"	553.645

GLENWOOD QUADRANGLE.

ELWELL, SOUTH ALONG BALTIMORE AND OHIO RAILROAD, TO GLENWOOD.

Elwell, road crossing; top of rail	560.2
Ben Lomond, road crossing; top of rail	559.2
Ben Lomond, 0.2 mile south of, railroad bridge 1841, north abutment, east of track; aluminum tablet stamped "557 ADJ 1903"	557.245
Apple Grove station, 570 feet north of, top of west end of railroad culvert; aluminum tablet stamped "579 ADJ 1903"	578.864
Apple Grove, road crossing; top of rail	578.1
Ashton, road crossing; top of rail	561.9
Ashton, 0.86 mile south of, 150 feet northeast of trestle over Eighteenmile Creek, 10 feet east of track, in top of squared stone foundation of water tank; aluminum tablet stamped "561 ADJ 1903"	561.071
Glenwood, 2,250 feet north of upper landing, 236 feet south of U. S. post light at foot of straight ripple, 125 feet north of mouth of Gwyno Run, on 15 by 10 bowlder 4 feet high; chiseled square (army engineers' bench mark 284–A)	517.797
Glenwood, road crossing; top of rail	558.8
Glenwood, bridge over small run, southwest abutment, north end of bridge seat; aluminum tablet stamped "544 ADJ 1903"	543.775

GLENWOOD, SOUTH ALONG HIGHWAY, TO SWANN; THENCE NORTHEAST TO ALBATROSS; THENCE NORTH TO DEBBY.

	Feet.
Glenwood, 2.84 miles south of, east of road, in face of rock outcrop; aluminum tablet stamped "592 ADJ 1903"	591.944
Glenwood, 5.9 miles south of, west of road, in face of rocky cliff; aluminum tablet stamped "587 ADJ 1903"	587.029
Swann, 0.1 mile north of, near church at northeast angle of forks of roads, under chestnut tree, on top of large stone; chiseled square	830.158
Swann, 2.3 miles northeast of, north of road, in face of rock ledge; aluminum tablet stamped "577 ADJ 1903"	577.045
Bryan, 0.6 mile northeast of, north of road, east end of face of rock cliff; aluminum tablet stamped "837 ADJ 1903"	837.152
Ellen, 2.1 miles east of, northwest of road, in shelf of outcrop of rock; aluminum tablet stamped "638 ADJ 1903"	638.021
Albatross, 0.08 mile northeast of, between road and run, in top of large rock; aluminum tablet stamped "701 ADJ 1903"	701.068
Albatross, 2.5 miles northeast of, Riverview schoolhouse, north corner stone; center of northeast face; aluminum tablet stamped "936 ADJ 1903"	936.106
Albatross, 6.7 miles north of, 300 feet northeast of saddle of ridge, west of road, in face of outcrop of rock; aluminum tablet stamped "846 ADJ 1903"	846.105
Siloam, 1.7 miles northeast of, bend of road to right on east side, in top of large stone; aluminum tablet stamped "660 ADJ 1903"	660.014
Flaxton, 0.11 mile north of, east of road, in shelf of outcrop of rock; aluminum tablet stamped "856 ADJ 1903"	856.092
Flaxton, 2 miles north of, north of road and creek at crossing of upper Ninemile Creek, in outcrop of rock; aluminum tablet stamped "638 ADJ 1903"	638.335

RAVENSWOOD QUADRANGLE.

AT SHERMAN.

Sherman, near Baltimore and Ohio Railroad station, on northwest pier of railroad bridge over Little Sandy Creek; chiseled square (U. S. Engineer Corps bench mark 216–A)	587.823
Sherman, 150 feet south of station, in north pier of railroad bridge, northeast corner of coping; aluminum tablet stamped "589 ADJ 1903"	588.681

AT RAVENSWOOD.

Ravenswood, top of northwest corner of north pier of Baltimore and Ohio Railroad bridge 128.4 over Sandy Creek; chiseled square (U. S. Engineer Corps bench mark 219–A)	585.617

MILLWOOD, ALONG BALTIMORE AND OHIO RAILROAD, TO GRAHAM STATION; THENCE WEST, ALONG HIGHWAYS, TO LOCUST GROVE SCHOOLHOUSE.

Millwood, on northeast corner of capstone of east pier of railroad bridge over Little Mill Creek, 9.5 feet west of center of track, 1 foot south by 1 foot east of northeast corner of pier; chiseled square, marked "U. S. B. M." (U. S. Engineer Corps bench mark 230–A)	577.868
Millwood, east pier of railroad bridge at south end; aluminum tablet stamped "578 ADJ 1903"	577.879
Letart, 0.9 mile southeast of, county bridge over Tombleson Run, in east end of northwest pier; bronze tablet stamped "569 ADJ 1903"	569.505
Letart, in front of station; top of rail	580.6
Graham station, 4.13 miles south of, dwelling east of highway, 15 feet west of track, in shelf of outcrop of rock; bronze tablet stamped "581 ADJ 1903"	581.207

	Feet.
Graham station, road crossing; top of rail	579.4
Graham, 0.4 mile west of, south of road, northeast of John Spencer's house, in shelf of rock; bronze tablet stamped "651 ADJ 1903"	651.009
Graham, 3.3 miles west of, west side of Union Church, 8 feet north of southwest corner, in stone foundation; bronze tablet stamped "681 ADJ 1903".	681.177

MILLWOOD, SOUTHEAST ALONG RAILROAD UP MILL CREEK, TO EVANS.

Angerona, 2.95 miles northwest of, south of track, 30 feet east of trestle over small run, in shelf of outcrop of rock; aluminum tablet stamped "589 ADJ 1903"	588.590
Angerona, road crossing near station; top of rail	583.1
Evans, 1.1 miles west of, at two schoolhouses, northeast corner stone of schoolhouse nearest track, in north face; bronze tablet stamped "642 ADJ 1903"	641.578
Evans, in front of station; top of rail	606.5

EVANS, WEST ALONG HIGHWAY, TO ROLLINS; THENCE SOUTH TO LEON; THENCE WEST TO DEBBY.

Evans, 2.4 miles southwest of, in southeast angle of forks of roads; iron post stamped "930 ADJ 1903"	929.925
Evans, 5.6 miles southwest of, west of road, at foot of steep grade, in top of low outcrop of rock; bronze tablet stamped "921 ADJ 1903"	920.767
Baden, 0.09 mile northeast of; northwest of road, in outcrop of rock; bronze tablet stamped "968 ADJ 1905"	967.737
Rollins, triangle at crossroads at run, in top of long stone planted 3 feet in ground; bronze tablet stamped "626 ADJ 1903"	625.758
Rollins, 3.3 miles south of, 0.2 mile north of road forks, northwest of road, south end of ledge of rock in top; bronze tablet stamped "665 ADJ 1903".	664.870
Leon, bridge over Thirteenmile Creek near mouth, north abutment, in west end of bridge seat; bronze tablet stamped "559 ADJ 1903"	558.863
Debby post-office, near Beech Hill station, railroad crossing; top of rail	567
Beech Hill, in front of station, opposite side of track, in west face of outcrop of rock; aluminum tablet stamped "572 ADJ 1903"	571.528

CEREDO, GUYANDOT, AND MILTON 15′ (HUNTINGTON AND KENOVA 30′) QUADRANGLES.

CABELL, LINCOLN, PUTNAM, AND WAYNE COUNTIES.

Leveling in 1901 in Ceredo, Guyandot, and Milton quadrangles by J. W. Hodges; and in the Guyandot and Milton quadrangles in 1907, by E. S. Dawson.

CEREDO 15′ (KENOVA 30′) QUADRANGLE.

KENOVA, EAST ALONG CHESAPEAKE AND OHIO RAILROAD, TO CENTRAL CITY.

	Feet.
Kenova, Union Station, in west side of door sill of men's entrance to waiting room; aluminum tablet stamped "567 K"	566.918
Ceredo, in front of station; top of rail	553.6
Kellogg, in front of station; top of rail	553
Kellogg, 1.3 miles east of, south of track, on small culvert; chiseled square.	564.59

CEREDO, SOUTHEAST ALONG NORFOLK AND WESTERN RAILWAY, TO SHOALS.

Ceredo, at road crossing near station; top of rail	569
Buffalo station, 7 feet from track, in southwest abutment of bridge over Buffalo Creek; aluminum tablet stamped "565 GRAFTON"	562.455
Buffalo, in front of station; top of rail	563

GUYANDOT 15′ (HUNTINGTON 30′) QUADRANGLE.

CENTRAL CITY, EAST ALONG CHESAPEAKE AND OHIO RAILROAD, TO BARBOURSVILLE.

	Feet.
Central City, in front of station; top of south rail of south track	549
Huntington, in front of station; top of rail	565
Huntington, southeast corner of Tenth street and Second avenue, between Chesapeake and Ohio and Baltimore and Ohio railroads, brick building occupied in 1899 by Sehon, Blake & Stevenson, wholesale grocery company, in west face of stone foundation, 18.8 feet south of west corner and 1.5 feet below floor (U. S. Engineer Corps bench mark 307-A)	547.463
Huntington, court-house at corner of Fourth avenue and Eighth street, in north corner of northeast entrance; aluminum tablet stamped "566 GRAFTON"	563.833
Wilson, at road crossing; top of rail	556
Barboursville, 0.5 mile north of, 3.1 miles east of Wilson station, in southeast abutment of railway bridge over Mud River; aluminum tablet stamped "572 ADJ 1903" (established as a substitute for bench mark destroyed in reconstruction of bridge)	571.760

SHOALS, SOUTH ALONG NORFOLK AND WESTERN RAILWAY, TO WAYNE.

Shoals station, at road crossing; top of rail	572
Lavalette, in front of station; top of west rail	565
Dickson, opposite mail crane at station; top of rail	581
Ardel (Herbert), opposite mail crane at station; top of rail	588
Ardel (Herbert post-office), across Twelvepole Creek, opposite M. E. parsonage, west of public highway, in large bowlder; bronze tablet stamped "591 GRAFTON"	588.585
Craig, in front of station; top of rail	597
Wayne, 1 mile north of, on coping stone at northeast corner of culvert; chiseled square	588.90

SHOALS, NORTHEAST TO HODGES.

Hodges, 125 feet north of road, opposite John Hodges's dwelling, on east of road leading to Huntington, in small bowlder; aluminum tablet stamped "710 GRAFTON"	708.184

HERBERT, NORTHEAST ALONG ROAD, TO SARAH; THENCE NORTH TO BARBOURSVILLE.

Bowen, 3.8 miles southwest of, on Booten Branch, 0.5 mile east of junction with Millers Fork, south of road, in bowlder; bronze tablet stamped "623 GRAFTON"	620.775
Poppa (Winslow), west of road nearly opposite post-office, in top of large bowlder; aluminum tablet stamped "612 GRAFTON"	609.584
Martha, northeast abutment of highway bridge over Guyandot River, in top stone; bronze tablet stamped "563 GRAFTON"	561.190

POPPA, SOUTH TO NEAR BARTRAM.

Bartram, 0.2 mile south of post-office, at mouth of small run, near store, in southeast corner of foundation of old barn of W. E. Adkins; aluminum tablet stamped "643"	642.267

MILTON 15′ (HUNTINGTON 30′) QUADRANGLE.

BARBOURSVILLE, EAST ALONG CHESAPEAKE AND OHIO RAILWAY, TO HURRICANE; THENCE ALONG HIGHWAY TO YOUNG'S STORE.

Ona, in W. T. Sanford's dwelling, in third stone from ground at northeast corner of foundation; bronze tablet stamped "634 GRAFTON"	631.957

	Feet.
Ona, at road crossing; top of rail	633
Milton, corner of railroad and Pike street, at southeast corner of street, in foundation stone of J. S. Kane's vacant store building; bronze tablet stamped "585 GRAFTON"	583.226
Milton, at road crossing; top of rail	585
Walton, opposite switch; top of rail	623
Hurricane, 0.1 mile west of station, opposite small highway bridge, north of track, in top stone of culvert; bronze tablet stamped "669 GRAFTON"	666.688

HAMLIN, SOUTHEAST ALONG PUBLIC HIGHWAYS, TO GRIFFITHSVILLE.

Sweetland, 0.2 mile east of post-office, 200 feet north of Middle Fork, north of road in bend, in rock bowlder; aluminum tablet stamped "657"	658.229

SALT ROCK, SOUTH ALONG HIGHWAYS, TO WEST HAMLIN.

West Hamlin, 300 feet east of station, in steps at northwest corner of Baptist Church; aluminum tablet stamped "595"	595.085

ONA, SOUTH, VIA FUDGES AND CAVILL CREEKS, TO GUYANDOT RIVER AT ROACH (SINGLE SPUR LINE).

Fudges (5 miles south of Ona), in stone chimney two stones above ground; bronze tablet stamped "736 GRAFTON"	733.360

HURRICANE, SOUTH TO NYE; THENCE SOUTHWEST TO HAMLIN; THENCE NORTHWEST TO SARAH.

Nye, in top stone of northwest pier of county bridge over Trace Fork of Mud River; bronze tablet stamped "625 GRAFTON"	623.468
Hamlin, in third stone from top in northeast end of abutment wall of bridge over Mud River; bronze tablet stamped "645 GRAFTON"	642.516
Salt Rock, in third stone from top in northeast end of retaining wall of highway bridge over Guyandot River; bronze tablet stamped "586 GRAFTON"	583.536

MIDKIFF AND WAYNE 15′ QUADRANGLES; HUNTINGTON AND WARFIELD 30′ QUADRANGLES.

LINCOLN AND WAYNE COUNTIES.

This work extends south from several bench marks in Guyandot and Milton quadrangles. The closure errors were somewhat excessive.

The leveling was done in 1907 by E. S. Dawson.

WAYNE 15′ (HUNTINGTON 30′) QUADRANGLE.

HERBERT, SOUTH ALONG NORFOLK AND WESTERN RAILWAY, TO PRESTON; THENCE NORTHEAST ALONG PUBLIC HIGHWAYS, TO COVER GAP; THENCE NORTH ALONG PUBLIC HIGHWAYS, TO A POINT 7 MILES NORTH OF NESTLOW.

	Feet.
Herbert, 2.2 miles south of, 450 feet south of road crossing, west of railroad and road, on rock in bank; chiseled square	596.76
Wayne, 3 feet north of main door in east side of Wayne County court-house; aluminum tablet stamped "707"	706.639
Wayne, 3.4 miles south of, 70 feet south of railroad crossing, in northwest abutment of railroad bridge over Patrick Creek; aluminum tablet stamped "607"	607.527
Sidney, in northeast abutment of iron railroad bridge over Twelvepole Creek at station; aluminum tablet stamped "626"	625.759
Sidney, 1.2 miles south of, 50 feet north of track, 50 feet south of Twelvepole Creek, in bluff opposite "slow" sign, on rock; chiseled square	636.82

	Feet.
Genoa, 150 feet west of station, in southwest corner of culvert; aluminum tablet stamped "647"	647.323
Genoa, 3 miles south of, 40 feet west of road crossing, 300 feet north of Towdey coal mine (abandoned), in abutment of iron bridge over Twelvepole Creek; aluminum tablet stamped "660"	660.071
Ferguson, 0.1 mile east of post-office, 300 feet west of Mr. Ferguson's house, in abutment of culvert over creek; aluminum tablet stamped "668"	668.407
Quaker, 0.9 mile south of post-office, south of road, in northwest abutment of iron bridge over Twelvepole Creek; aluminum tablet stamped "685"	684.895
Quaker, 2.2 miles south of, 70 feet east of county road, 200 feet east of mile-post "N 528–C 184," on center of abutment at north end of iron bridge 978; chiseled square	687.44
Dunlow, 1.7 miles southeast of, 40 feet east of county road, 0.5 mile northwest of Preston, east bank of railroad, on sandstone; chiseled square	702.89
Preston, 2.8 miles northeast of, on north side of Missouri Creek, 140 feet east of hollow to right, 600 feet west of foot of mountain, on sandstone; chiseled square	889.35
Preston, 4 miles northeast of, 300 feet west of Fork Run, 150 feet west of small house, 0.6 mile west of mountain foot, south of road, north of Milam Creek, in large bowlder; aluminum tablet stamped "832"	832.334
Preston, 6 miles northeast of, 0.1 mile east of old dam, 0.1 mile west of East Fork, in Milam Creek, on large sandstone; chiseled square	734.51
Spry, 0.7 mile southwest of, north of old sawmill, 0.5 mile west of mouth and 10 feet north of Milam Creek, 600 feet east of house, in bowlder; aluminum tablet stamped "708"	708.215
Spry, 1 mile north of, east of road, 150 feet east of Twelvepole Creek, in bank, on sandstone; chiseled square	714.71
Spry, 2 miles north of, south of road on top of small summit, 100 feet north of road forks, in sandstone; aluminum tablet stamped "697"	697.360
Kiahsville, 0.3 mile southeast of post-office, east of road, 300 feet east of mouth of Cove Creek, 300 feet from ford, in large bowlder; aluminum tablet stamped "674"	674.606
Kiahsville, 3.6 miles east of, north of Cove Creek, south of road, 200 feet east of house, 800 feet east of old sawmill, in sandstone; aluminum tablet stamped "762"	761.814
Covegap, 2 miles northwest of, east of road, halfway down hill to divide, in bank on edge of road, in sandstone; aluminum tablet stamped "1152"	1,152.275
Covegap, 3.45 miles north of, west of road, 60 feet north of road fork to Four-mile Creek, 80 feet north of summit, on edge of road, in sandstone; aluminum tablet stamped "1178"	1,177.933
Covegap, 4.8 miles north of, west of road in hollow, 70 feet west of graveyard, on sandstone; chiseled square	1,174.15
Covegap, 8.4 miles north of, at head of Beech Fork, 200 feet west of store at mountain foot, north of Beech Fork, south of road opposite hollow, in sandstone; aluminum tablet stamped "871"	871.146
Nestlow, 0.4 mile north of post-office, 10 feet east of Beech Fork and west of road, 0.2 mile north of store, on sandstone; chiseled square	767.42
Nestlow, 3.45 miles north of, north of road, north of Beech Fork, 400 feet west of mouth of Wolfpen Branch, 0.1 mile east of schoolhouse and church, in large bowlder; aluminum tablet stamped "694"	693.536

MIDKIFF 15′ (HUNTINGTON 30′) QUADRANGLE.

WEST HAMLIN, SOUTH ALONG PUBLIC HIGHWAYS, TO COVEGAP.

	Feet.
Sheridan. 100 feet east of railroad, west of road at forks near small white house by beech tree, in sandstone; aluminum tablet stamped "601"...	601.487
Laverne post-office (Brown City station), 70 feet west of railroad, in sandstone foundation of chimney southeast corner of house; aluminum tablet stamped "604".....	604.279
Midkiff, 1 mile south of, under fence west of railroad and road, in front of old house and store called "Rockville," 600 feet north of Tenmile Creek, in rock; aluminum tablet stamped "599".....	599.404
Bradyville, 1.8 miles south of, south of railroad, north of road, near east end of tangent, near whistle post, in sandstone; aluminum tablet stamped "609".....	608.515
Ranger, 2.05 miles south of, east of Fourteenmile Creek by blacksmith shop, 0.4 mile south of East Fork, in sandstone outcrop; aluminum tablet stamped "605".....	605.485

WEWANTA, SOUTHEAST ALONG HIGHWAYS, TO FERRELLBURG; THENCE NORTH ALONG HIGHWAYS, TO GRIFFITHVILLE.

Fourteen, 0.8 mile east of post-office, in bank, halfway up mountain, north of road, in sandstone; aluminum tablet stamped "1052".....	1,052.353
Atensville, 0.25 mile northwest of, east of railroad between Eden Park and Atenville stations, opposite mouth of Dry Branch, in southeast end of culvert, in sandstone; aluminum tablet stamped "617".....	618.034
Fry, in south abutment of culvert over Green Shoal Branch, fourth stone from top; aluminum tablet stamped "603".....	603.876
Fry, 2.9 miles northeast of, 300 feet north of house, 0.2 mile north of mouth of Abbott Branch and sawmill, west of road, west of Big Ugly Creek, in large bowlder; aluminum tablet stamped "634".....	634.528
Leet, 2 miles north of, east of run, west of road, 300 feet north of foot of mountain and head of Big Creek, in bowlder; aluminum tablet stamped "675".....	675.825
Leet, 5.5 miles north of, south of Upton Branch, 0.5 mile east of head of Upton Branch, in bank near hollow, in large rock; aluminum tablet stamped "834".....	834.555
Leet, 6.75 miles north of, north of road, east of Upton Branch, along edge, 300 feet north of foot of mountain, on sandstone; chiseled square.....	747.68
Spurlockville, 1.1 miles northwest of, west of road and Mud River, on edge of small summit, in sandstone; aluminum tablet stamped "726".....	727.023
Palermo, 0.4 mile northwest of post-office, 50 feet west of mouth of Parsner Creek, 50 feet north of Mud River, west of road forks, in sandstone; aluminum tablet stamped "691".....	692.360
Bernie, 0.8 mile west of, east of Parsner Creek, in bank opposite hollow, on rock; chiseled square.....	751.65
Bernie, 0.1 mile west of post-office, north of Parsner Creek and road, opposite old sawmill, in large sandstone; aluminum tablet stamped "807"...	808.062
Bernie, 3 miles north of, east of road, east of Sycamore Fork, on top of small hill, opposite house, in rock cliff; aluminum tablet stamped "715"....	716.099
Bernie, 3.8 miles north of, east of road, east of Sugar-tree Fork, opposite house and hollow, on rock cliff; chiseled square.....	664.608

GRIFFITHSVILLE, NORTHWEST TO HAMLIN.

	Feet.
Griffithsville, 1 mile northwest of post-office, west of road, west of Middle Fork, in bank on small hill, in rock cliff; aluminum tablet stamped "667"	668.319
Griffithsville, 3.4 miles northwest of, east side of Middle Fork, at mouth of Seary Creek, on sandstone; chiseled square	648.60

WARFIELD 30′ QUADRANGLE.

NEAR PRESTON.

Preston, 0.6 mile east of, 800 feet east of Wells Branch station, in northwest abutment of bridge 975 over mouth of Missouri Branch at mouth; aluminum tablet stamped "704"	704.665

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RESULTS

OF

SPIRIT LEVELING IN WEST VIRGINIA

1896 TO 1908, INCLUSIVE

COMPILED BY

S. S. GANNETT AND D. H. BALDWIN

IN COOPERATION WITH THE WEST VIRGINIA STATE GEOLOGICAL SURVEY
DURING 1901 TO 1908, INCLUSIVE

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RESULTS OF SPIRIT LEVELING IN WEST VIRGINIA, 1896 TO 1908, INCLUSIVE.

Compiled by S. S. GANNETT and D. H. BALDWIN.

INTRODUCTION.

Scope of the work.—The results herein given are based on a common mean sea-level datum. The main control is the adjustment made in 1903 by the Coast and Geodetic Survey of a great net of precise levels which combines work of various organizations and covers the eastern half of the United States. The precise-level lines which traverse West Virginia are the "transcontinental" line of the Coast and Geodetic Survey following the Baltimore and Ohio Railroad from Corinth to Parkersburg; the Baltimore and Ohio precise-level line from Harpers Ferry via Cumberland and Grafton to Moundsville; the precise levels of the Ohio River survey by the Corps of Engineers, U. S. Army; and two lines by the United States Geological Survey from Grafton north along the Baltimore and Ohio Railroad to the state line and from Alleghany west to Charleston. The results of adjustments of the Ohio River survey line are given by the Coast and Geodetic Survey only for junction points with other precise lines; the adjusted heights at other points were interpolated by the United States Geological Survey. The portion of the Baltimore and Ohio line lying between Cumberland, Md., and Benwood, W. Va., is recent work and did not form part of the data involved in the net adjustment, but an adjustment has been made of this line and corrections made to the primary leveling in agreement.

All results of spirit leveling in this State previously published by the United States Geological Survey and all later work are included in this report, readjusted, and rearranged by quadrangles. Descriptions and elevations of bench marks are given for 48 counties, furnishing vertical control for nearly half the State.

Personnel.—The field work for the years 1896 to 1906, inclusive, was done under the direction of H. M. Wilson, geographer, and for

the years 1907 and 1908 under Frank Sutton, geographer, in 1908 under the general supervision of R. B. Marshall, chief geographer.

Credit is given to the various level men directly in charge under the heading of each list.

The office work of adjustment was principally done by D. H. Baldwin, topographer, under the immediate supervision of S. S. Gannett, geographer, and since 1907 under the general direction of E. M. Douglas, geographer.

Methods of determination.—The lists are arranged according to the degree of accuracy of the method used in their determination, precise and primary. Under precise leveling are included either lines run in both forward and backward directions or simultaneous double-rodded lines, a high-grade instrument being used and special precautions being taken in observations and reduction to correct errors and make the line continuously good throughout. Under primary leveling are included lines run mostly single with the Y level, precautions being taken against only the principal sources of error, and depending upon the closure of circuits for a check. The allowable limit of error observed on the double-simultaneous precise line from Grafton, W. Va., to Pittsburg, Pa., by the Geological Survey is represented in feet by the formula $0.04\sqrt{D}$, and the limit observed on the precise line from Alleghany to Charleston, by the forward and backward method, by the formula $0.017\sqrt{D}$, in which D is the distance between bench marks in miles. The limit in feet on primary work is $0.05\sqrt{D}$, in which D is the length of circuit in miles.

Bench marks.—The bench marks described in the following list are mainly of three general forms: First, a circular bronze or aluminum tablet 3½ inches in diameter and one-fourth inch thick, appropriately lettered, having a 3-inch stem cemented into a drill hole, generally in the vertical walls of public buildings, bridge abutments, or other substantial masonry structures. The second form, employed where masonry or rock is not accessible, consists of a hollow wrought-iron post 4 feet in length and 3.5 inches in outer diameter, split at the bottom and expanded to 10 inches, so as to prevent both the easy subsidence of the post and the malicious pulling of it out of the ground. The iron is heavily coated with asphalt, and over the top of the post is riveted a bronze tablet similar to that described above. The third form consists of a copper bolt 1 inch in diameter and 4 inches long, which is split at one end and expanded in a drill hole in masonry by driving on a brass wedge. But few bench marks of the third class have been used in this State, and their use has now been discontinued.

The numbers stamped upon the bench marks as described in the following lists represent the elevations to the nearest foot above mean

sea level, as determined by unadjusted levels in the field. The notes have since been subjected to changes resulting from the adjustments necessary to close circuits and to those resulting from reduction to mean sea level through readjustment of the precise-level net of the United States, and therefore in some cases the finally accepted elevations as printed herein differ from those submitted as bench-mark numbers by 1 or 2 feet. This method of numbering bench marks has been adopted where many levelmen are working in the same area at the same time, as less liable to lead to confusion in identification of bench marks than any attempt at serial numbering, and because the bench-mark number at the same time gives an approximate statement of the elevation. It is assumed that engineers and others finding these bench marks so stamped in the field will communicate with the Director of the United States Geological Survey in order to obtain the accepted elevation to hundredths or thousandths of a foot. Bench marks established under cooperation with the State of West Virginia are stamped with the state name.

Any person finding bench marks in the following lists mutilated or destroyed will confer a favor by notifying the Director, United States Geological Survey, Washington, D. C.

PRECISE LEVELING.

BLACKSVILLE, FAIRMONT, AND MORGANTOWN QUADRANGLES.

MARION, MONONGALIA, AND TAYLOR COUNTIES.

The elevations in the following list are a portion of the result of a line of precise levels run in 1899 from Grafton, W. Va., to Pittsburg, Pa., by E. L. McNair. This line was included in the adjustment of the precise-level net made in 1903 by the Coast and Geodetic Survey, with the result that the elevation by the original line was lowered at Braddock, Pa., 0.112 foot with respect to Grafton in a total distance of 142.5 miles, and 0.053 foot of this error has been adjusted into this West Virginia portion.

The double-simultaneous method was employed with a Buff & Berger precise level and two double-faced 10-foot nonextensible target rods.

GRAFTON, NORTH ALONG BALTIMORE AND OHIO RAILROAD, VIA FAIRMONT AND MORGANTOWN, TO STATE LINE.

FAIRMONT QUADRANGLE.

	Feet.
Grafton, Baltimore and Ohio Railroad bridge across Tygart River, at north end of central pier, on coping stone; chisel mark (Coast and Geodetic Survey bench mark "M")	996.856
Grafton, in front of station; top of rail on main line	1,000.5

	Feet.
Valley Falls, 2.9 miles east of, bridge seat at northeast corner of girder bridge 104, 7 feet east of center of track, 4 feet below top of outer rail of curve; bronze tablet stamped "986 PITTSBURG 1899"	985.601
Bush, in front of flag station; top of south rail	985.2
Valley Falls, in front of station; top of north rail	974.9
Powells, in front of flag station; top of south rail	907.6
Powells, 0.67 mile west of flag station, stone-arch bridge 108, coping of stone wall, 1.1 feet below top of rail, 7 feet north of center of track; aluminum tablet stamped "899 PITTSBURG 1899"	899.043
Colfax, in front of station; top of south rail	891.9
Bentons Ferry, at signboard; top of south rail	889.9
Bentons Ferry, 160 feet south of signboard, bridge seat at southwest corner of girder bridge 111, 4.5 feet below top of rail and 18.5 feet south of center of track; bronze tablet stamped "885 PITTSBURG 1899"	885.094
Fairmont, in front of Baltimore and Ohio station; top of east rail	883.6
Fairmont, 1.25 miles north of, Baltimore and Ohio Railroad bridge 371 across Monongahela River, at north end of east abutment in coping stone; bronze tablet stamped "885 PITTSBURG 1899"	885.034

BLACKSVILLE QUADRANGLE.

Hoult, in front of station; top of west rail	882.4
Rivesville, in front of flag station; top of east rail	881.3
Montana, in front of station; top of east rail	875.4
Catawba, 0.8 mile south of, Baltimore and Ohio Railroad 1-span truss bridge 369, in coping stone at north end of east abutment, 3 feet below and 8 feet north of rail; bronze tablet stamped "873 PITTSBURG 1899"	872.605
Catawba, in front of station; top of north rail	873.0
Luther, in front of station; top of east rail	867.9
Murray (Scottdale post-office), in front of station; top of north rail	868.0
Opekiska, in front of station; top of north rail	866.2
Beechwood, in front of station; top of south rail	860.2
Little Falls, 1.33 miles northwest of, 9.5 feet west of and 4 feet above west rail, 0.5 mile north of bridge 366, in face of rock bluff; bronze tablet stamped "859 PITTSBURG 1899"	858.844
Little Falls, in front of station; top of north rail	847.3

MORGANTOWN QUADRANGLE.

Uffington, in front of station; top of north rail	831.3
Uffington, 400 feet north of station, in coping stone of abutment at northwest corner of 1-span truss bridge 364, 3 feet below and 7 feet north of top of rail; aluminum tablet stamped "828 PITTSBURG 1899"	827.883
Russell siding; east rail	822.6
Morgantown, 480 feet south of Baltimore and Ohio station, in coping stone of abutment at northwest corner of truss bridge over Deckers Creek; bronze tablet stamped "821 PITTSBURG 1899"	820.870
Morgantown, in front of Baltimore and Ohio station; top of east rail	823.1
Randall, in front of flag station; top of east rail	824.5
Van Voorhis, 1 mile south of, in bridge seat at southeast corner of steel-girder bridge 359; bronze tablet stamped "815 PITTSBURG 1899"	815.218
Van Voorhis, in front of station; top of west rail	818.0
Hoard, in front of flag station; top of east rail	817.0
State line (West Virginia–Pennsylvania) post; top of east rail	815.3

CHARLESTON, HINTON, KANAWHA FALLS, LEWISBURG, AND RALEIGH 30′ QUADRANGLES; CHARLESTON SPECIAL, FAYETTEVILLE, AND MONTGOMERY 15′ QUADRANGLES.

FAYETTE, GREENBRIER, KANAWHA, RALEIGH, AND SUMMERS COUNTIES.

The following are the adjusted results of a line of precise levels extended from precise leveling in Virginia and North Carolina; the closure error, using the Kanawha River survey levels of the army engineers to complete the line from Charleston to the Ohio River, was +0.732 foot upon the 1903 adjustment at Point Pleasant. This error has been adjusted through the entire line from Greensboro, N. C., the West Virginia portion being corrected by amounts proportionate to the mileage, between −0.44 foot at Alleghany and −0.732 foot at Lock 6, or at a rate of about 0.002 foot per mile.

The prism level and yard rods were used and the latest methods employed.

The leveling was done in 1907 by C. H. Semper, level man.

ALLEGHANY TUNNEL, VA., WEST ALONG CHESAPEAKE AND OHIO RAILWAY, TO HINTON; NORTHWEST TO GAULEY, W. VA.; THENCE NORTHWEST, ALONG KANAWHA AND MICHIGAN RAILWAY, TO CHARLESTON AND LOCK 6.

LEWISBURG 30′ QUADRANGLE.

	Feet.
Tuckahoe, in front of station; top of rail	2,036.5
Tuckahoe, 2.03 miles west of, 15 feet west of milepost "CIN 355," south of track, in face of wall in rock cut; aluminum tablet stamped "1981"	1,980.335
White Sulphur, in front of station; top of rail	1,923.3
White Sulphur, 546 feet north of station, in northwest corner of brick church; aluminum tablet stamped "1915"	1,914.100
Dickson, in front of station; top of rail	1,835.4
Dickson, 0.33 mile west of, in top of abutment at west end of bridge over highway; aluminum tablet stamped "1790"	1,789.207
Harts Run, in front of signboard; top of rail	1,818.0
Caldwell, in front of signboard; top of rail	1,764.0
Caldwell, 0.56 mile west of, in top of north side of west abutment of steel bridge; aluminum tablet stamped "1745"	1,744.562
Whitcomb, 500 feet east of, in top of north side of west abutment of bridge over river; aluminum tablet stamped "1700"	1,699.570
Whitcomb, in front of station; top of rail	1,700.7
Ronceverte, in front face of First National Bank Building; aluminum tablet stamped "1666"	1,665.036
Ronceverte, in front of station; top of rail	1,663.8
Ronceverte, 3.22 miles west of, 240 feet east of milepost "CIN 339," in foundation of semaphore pole; aluminum tablet stamped" 1659"	1,658.111

HINTON 30′ QUADRANGLE.

Rockland, in front of station; top of rail	1,654.7
Fort Spring, in front of station; top of rail	1,624.4
Fort Spring, directly opposite station, at margin of highway, in railroad retaining wall; aluminum tablet stamped "1622"	1,621.565

	Feet.
Frazier, in front of signboard; top of rail	1,610.5
Fort Spring, 2.92 miles west of, 230 feet east of milepost "CIN 333," in face of rock wall; aluminum tablet stamped "1593"	1,592.730
Half Way, in front of station; top of rail	1,586.5
Alderson, northwest corner of front face of Merchant Grocery Company Building; aluminum tablet stamped "1556"	1,555.074
Alderson, in front of station; top of rail	1,550.9
Mohler, in front of station; top of rail	1,543.7
Alderson, 2.52 miles west of, west of track, 0.38 mile south of milepost "CIN 327," in top of railroad culvert; aluminum tablet stamped "1534"	1,533.252
Riffe, in front of station; top of rail	1,523.2
Alderson, 6.13 miles west of, at milepost "CIN 323," in face of rock; aluminum tablet stamped "1525"	1,524.209
Pence Springs, in front of station; top of rail	1,530.2
Pence Springs, 0.42 mile west of, in foundation of semaphore pole; aluminum tablet stamped "1531"	1,530.564
Lowell, in front of station; top of rail	1,516.8
Talcott, northwest corner of foundation under Chesapeake and Ohio Railway station; aluminum tablet stamped "1514"	1,513.329
Hilldale, 175 feet west of, in stone step on north side of track; aluminum tablet stamped "1509"	1,508.265
Hilldale, 2.53 miles west of, 65 feet west of milepost "CIN 313," in face of rock wall; aluminum tablet stamped "1455"	1,454.374
Wiggins, in front of station; top of rail	1,441.5
Wiggins, 2.72 miles west of, in foundation of semaphore pole; aluminum tablet stamped "1395"	1,394.665
Hinton, in northwest corner of Chesapeake and Ohio Railway station; aluminum tablet stamped "1388"	1,385.212
Hinton, in front of station; top of rail	1,382.2
Hinton, 3.05 miles west of, 260 feet west of milepost "CIN 305," north of track, in bridge seat at east end; aluminum tablet stamped "1350"	1,349.715
Brooks, in front of signboard; top of rail	1,341.8
Hinton, 6.04 miles west of, 250 feet west of milepost "CIN 302," south of track, in railroad culvert; aluminum tablet stamped "1329"	1,328.047
Sandstone, 0.31 mile east of, west side of railroad bridge, in north abutment; aluminum tablet stamped "1292"	1,291.732
Sandstone, in front of station; top of rail	1,293.0
Meadow Creek, in front of station; top of rail	1,272.9
Meadow Creek, 0.2 mile west of, in top of west abutment at north side of railroad bridge; aluminum tablet stamped "1269"[a]	1,270.126
Meadow Creek, 2.75 miles west of, north of track, in top of east end of railroad culvert; aluminum tablet stamped "1252"	1,250.998

RALEIGH 30′ QUADRANGLE.

Glade, in front of station; top of rail	1,242.2
Glade, 0.75 mile west of, north of track, 250 feet west of milepost "CIN 290," in top of railroad culvert; aluminum tablet stamped "1233"	1,232.434
Quinnimont, 40 feet south of station, in top of north abutment at west side of railroad bridge; aluminum tablet stamped "1200"	1,199.058
Quinnimont, in front of station; top of rail	1,201.5

[a] In accordance with report of R. W. Mumford, division engineer, Chesapeake and Ohio Railway, that the above bench mark was reestablished at same description but 19 inches greater elevation, its equivalent 1.58 feet was added to the original elevation for the bench mark in addition to the adjustment correction.

	Feet.
Prince, in front of station; top of rail	1,191.4
McKendree, 0.21 mile east of, 85 feet east of milepost "CIN 282," north of track, in face of bowlder; aluminum tablet stamped "1137"	1,136.459
McKendree, in front of station; top of rail	1,130.5
Thayer, in front of signboard; top of rail	1,111.3
Thayer, 60 feet east of signboard, south of track, in top of west abutment of railroad bridge; aluminum tablet stamped "1111"	1,110.018
Alaska, in front of signboard; top of rail	1,095.8
Claremont, in front of station; top of rail	1,089.8
Stone Cliff, 0.17 mile east of, in foundation of semaphore pole; aluminum tablet stamped "1083"	1,082.060
Stone Cliff, in front of station; top of rail	1,079.3
Thurmond, in front of station; top of rail	1,070.9
Thurmond, in north abutment on west side of railroad bridge over New River; aluminum tablet stamped "1068"	1,067.457
Rush Run, in front of station; top of rail	1,045.7
Beury, in front of signboard; top of rail	1,037.8
Beury, 160 feet east of signboard, in top of west abutment at north side of railroad culvert; aluminum tablet stamped "1036"	1,035.596
Fire Creek, in front of station; top of rail	1,034.2
Sewell, 0.58 mile north of, 170 feet east of milepost "CIN 268," in foundation of semaphore pole; aluminum tablet stamped "1011"	1,010.113
Sewell, in front of station; top of rail	1,008.2

FAYETTEVILLE 15′ (KANAWHA FALLS 30′) QUADRANGLE.

Caperton, in front of station; top of rail	991.0
Keeney Creek, in front of signboard; top of rail	968.8
Nuttall (Nuttallburg post-office), 0.56 mile east of, north of track, in top of east abutment to railroad culvert; aluminum tablet stamped "959"	958.091
Nuttall, in front of station; top of rail	949.5
Nuttall, 1.47 miles west of, 220 feet west of milepost "CIN 262," west of track, in face of large rock; aluminum tablet stamped "924"	923.546
Fayette, in front of station; top of rail	899.9
Newlyn, in front of signboard; top of rail	880.9
Elmo, in front of signboard; top of rail	870.6
Fayette, 1.81 miles west of, 200 feet west of milepost "CIN 259," north of track, in face of large rock; aluminum tablet stamped "868"	867.085
Sunnyside, in front of signboard; top of rail	849.7
Hawks Nest, in front of station; top of rail	834.5
Hawks Nest, 0.22 mile west of, south of track, in top of abutment at east end of railroad bridge over New River; aluminum tablet stamped "834"	832.873
Cotton Hill, in front of station; top of rail	794.7
Cotton Hill, 1.14 miles west of, 150 feet south of milepost "CIN 253," 7 feet east of track, in top of large rock; aluminum tablet stamped "771"	770.240
Gauley, in front of station; top of rail	720.0
Gauley, 400 feet north of Chesapeake and Ohio station, in top of south abutment at west side of bridge over New River; aluminum tablet stamped "712"	711.842
Gauley Bridge station, on Kanawha and Michigan Railway, at top step of wing wall in south face of abutment at west end of bridge over highway; aluminum tablet stamped "677 KNWA" (old bench mark—elevation given in 21st Annual Report, 677.086)	676.543
Glen Ferris, in front of station; top of rail	673.3

	Feet.
Kanawha Falls, 180 feet south of flag station of Kanawha and Michigan Railway, 200 feet north of railway crossing, west of track, nearly opposite house of T. W. Farley, in face of rock at base of cliff; bronze tablet stamped "667 KNWA" (old bench mark—elevation given in 21st Annual Report, 667.121)	666.540
Falls View, in front of station; top of rail	652.9

MONTGOMERY 15′ (KANAWHA FALLS 30′) QUADRANGLE.

Boomer, in front of station; top of rail	644.9
Harewood, in front of station; top of rail	643.0
Longacre, in front of station; top of rail	645.1
Smithers, in front of station; top of rail	640.4
Cannelton, in front of station; top of rail	638.8
Cannelton, 1.03 miles west of, in east face of masonry near north end of Kanawha Lock 2; bronze tablet stamped "614 KNWA" (old bench mark—elevation given in 21st Annual Report, 614.205)	613.485
Lock 2, top of coping over tablet (elevation given in 21st Annual Report, 614.530)	613.808
London, in front of station; top of rail	636.0
London, 395 feet north of, east of track, in top of railroad culvert; aluminum tablet stamped "636"	635.334
Hugheston, in front of station; top of rail	629.1
Riverside, in top of coping stone at northwest corner of head of Lock 3; aluminum tablet stamped "606"	605.466
Riverside, in front of signboard; top of rail	626.5
Cedar Grove, in front of station; top of rail	619.5
Cedar Grove, 1.95 miles west of, in top of bridge seat in east abutment at north side of railroad culvert; aluminum tablet stamped "618"	617.316
Shrewsbury, in front of station; top of rail	617.2

PEYTONA (CHARLESTON 30′) QUADRANGLE.

Dickinson, in inside face of wall around turntable; aluminum tablet stamped "620"	619.064
Dickinson, in front of station; top of rail	622.2
Belle, in front of signboard; top of rail	613.4
Belle, 110 feet west of signboard, north of track, in top of railroad culvert; aluminum tablet stamped "611"	609.962
Piatt, in front of signboard; top of rail	611.8

CHARLESTON SPECIAL (CHARLESTON 30′) QUADRANGLE.

Heskett, in front of signboard; top of rail	616.4
Heskett, 80 feet north of, west of track, in top of north abutment to railroad culvert; aluminum tablet stamped "614"	612.976
Malden, in front of station; top of rail	612.3
Dana, in front of station; top of rail on Kanawha and Michigan Railway track	608.5
Dana, 1.03 miles west of, south of track, 230 feet east of milepost "G B 33," in top of large rock; aluminum tablet stamped "598"	597.458
Charleston, in north face of Kanawha and Michigan Railway station, under window of ticket office; aluminum tablet stamped "601"	600.935

	Feet.
Charleston, in northwest corner of state capitol; bronze tablet stamped "602 C" (old bench mark)	600.703
Charleston, in front of station; top of rail	597.7
Charleston, in front of Park street station; top of rail	604.9
West Charleston, in front of station; top of rail	601.3
Charleston, 4.86 miles west of, at hollow quoin stone of lower gate, in top of coping stone of north wall of Lock 6; chiseled square (army engineers' bench mark—elevation, 565.5)	569.355

PRIMARY LEVELING.

WILLIAMSPORT QUADRANGLE.

BERKELEY COUNTY.

Leveling done in 1908 by J. M. Harris. Part of single spur from Hagerstown to be extended in 1909 to Martinsburg.

POTOMAC RIVER BRIDGE SOUTH OF WILLIAMSPORT, MD., SOUTHWEST ALONG CUMBERLAND VALLEY RAILROAD, TO FALLING WATERS.

	Feet.
Williamsport station, 1.5 miles southwest of, railroad bridge 82–1 over Potomac River; top of rail near west end	380.8
Williamsport station, 2.3 miles southwest of, in top of southwest corner of west bridge seat of railroad bridge 82–2; aluminum tablet stamped "363".	362.647
Williamsport station, 3.4 miles southwest of; on top of west foundation at north end of water tank	361.485
Falling Waters, 500 feet east of, railroad bridge 85; northeast corner of east bridge seat	359.160
Falling Waters, in front of station; top of rail	372.3
Falling Waters, 0.6 mile southwest of, at telephone pole "85–31," in center of south head wall in top of concrete box culvert under railroad; aluminum tablet stamped "404"	404.335

MARTINSBURG AND MIDDLETOWN QUADRANGLES.

JEFFERSON COUNTY.

Leveling in 1907 by W. R. Winstead.

Elevations in Maryland and Virginia on these quadrangles will be published in another bulletin.

MIDDLETOWN QUADRANGLE.

AT HARPERS FERRY.

	Feet.
Harpers Ferry, on northwest corner of south end of west abutment of road bridge near toll office; point marked "U. S. B. M. 279"	279.23
Harpers Ferry, in front face of post-office on south side of main entrance; aluminum tablet stamped "ADJ 275"	274.645

MARTINSBURG QUADRANGLE.

AT SHEPHERDSTOWN.

	Feet.
Shepherdstown, in front face of post-office, 3 feet east of main entrance; aluminum tablet stamped "ADJ 406"	405.671

FLINTSTONE, FROSTBURG, HANCOCK, AND PAWPAW QUADRANGLES.

BERKELEY, MINERAL, AND MORGAN COUNTIES.

Leveling in Frostburg and Flintstone quadrangles in 1897 by Hargraves Wood, and in Pawpaw and Hancock quadrangles in 1898 by C. B. Bailey, and in 1899 by Chas. M. Smith.

PATTERSON CREEK SOUTH TO ALASKA.

FLINTSTONE QUADRANGLE.

	Feet.
Patterson Creek, north end of Baltimore and Ohio Railroad bridge over Patterson Creek, north side of track, in ballast wall; copper plug marked "574 C"	574.327

FROSTBURG QUADRANGLE.

Frankfort (Alaska), 0.5 mile northwest of, in west end of north abutment of highway bridge over Patterson Creek; copper bolt stamped "589 C".	589.257

HANCOCK QUADRANGLE.

HANCOCK, SOUTHWEST ALONG HIGHWAY VIA BERKELEY SPRINGS, TO ROCK GAP.

Berkeley Springs, west face of southwest corner stone of Morgan County court-house; aluminum tablet stamped "612 C" (reported destroyed, court-house torn down)	612.085

STOTLERS CROSSROADS, NORTHEAST AND EAST ALONG SLEEPY CREEK, TO CHERRY RUN, MD.

Stotlers Crossroads, 0.5 mile north of; at first ford of Sleepy Creek, ledge of rock east side of road, 0.25 mile north of north entrance to ford, in cleft of rock about 4 feet above roadway; aluminum tablet stamped "662 C".	662.244

M'COY'S FERRY, SOUTH UP BLACK CREEK (DOUBLE-TARGETED SPUR LINE).

Johnstown, 1.2 miles south of; on an outcrop of sandstone rock about 125 feet east of road forks and 2.5 miles west of Hedgesville; three small pines stand just south; chiseled square	561.51
Tomahawk, in northeast corner of foundation stone of W. W. Hedges's barn; aluminum tablet stamped "466 C"	466.577

PAWPAW QUADRANGLE.

ROCK GAP, EAST TO STOTLER'S CROSSROADS.

Rock Gap, 700 feet west of Fearnow's house; 10 feet north of road at summit of gap, in rock, aluminum tablet stamped "761 C"	760.946

GREAT CACAPON, VIA LONG HOLLOW RUN, TO FISHER FORD (DOUBLE-TARGETED SPUR LINE).

Great Cacapon, Md., on Lock 55 of Dam No. 6; U. S. C. & G. S. bench mark "C"	444.128
Fisher Ford, in large bowlder southeast corner of road; aluminum tablet stamped "MARYLAND 543 C"	543.505

BRUCETON, MORGANTOWN, BLACKSVILLE, AND MANNINGTON QUADRANGLES.

PRESTON, MONONGALIA, MARION, AND WETZEL COUNTIES.

Leveling in Morgantown quadrangle in 1899 by W. Crennell, in Blacksville quadrangle in 1901 by M. Page, in Mannington quadrangle in 1902 by J. W. Hodges, and in Bruceton quadrangle in 1902 by F. T. Willis.

MORGANTOWN QUADRANGLE.

MORGANTOWN, SOUTHEAST, VIA DELLSLOW, TO MASONTOWN, RETURNING WESTWARD AND NORTH, VIA COLD SPRING, TO MORGANTOWN.[a]

	Feet.
Morgantown, 0.4 mile east of, on southeast corner of east abutment of first bridge over Deckers Creek; chisel mark	820.55
Morgantown, 0.9 mile east of, on northwest corner of east abutment of second bridge over Deckers Creek; chisel mark	823.30
Morgantown, 3.9 miles east of, at Johnson's mills, on bridge seat at northeast corner of west abutment of third bridge over Deckers Creek; chisel mark	890.14
Dellslow, north side of creek, 30 feet east of bridge over creek, in top of large bowlder; aluminum tablet stamped "994 PITTSBURG 1899"	993.846
Dellslow, 4.8 miles south of, on south side of east abutment of covered bridge over Deckers Creek; chisel mark	1,454.81
Masontown, in southeast corner of foundation of Methodist Church; aluminum tablet stamped "1843 PITTSBURG"	1,842.421
Cold Spring, 0.5 mile north of, near watering trough west of pike, in large sandstone; aluminum tablet stamped "2113 PITTSBURG"	2,112.571

CHEATHADEN, SOUTH TO LAUREL IRON WORKS.

Laurel Iron Works, 150 feet east of, in southeast bridge seat; aluminum tablet stamped "1055 PITTSBURG"	1,054.834

BRUCETON QUADRANGLE.

MASONTOWN, W. VA., SOUTHEAST ALONG HIGHWAY, TO ALBRIGHT; THENCE NORTHEAST, TO LENOX; THENCE NORTHWARD, VIA BRUCETON MILLS, TO ELLIOTTSVILLE, PA.

Herring, in southwest corner of stone foundation of church; bronze tablet stamped "2042 GRAFTON"	2,042.080
Herring, 4.3 miles southeast of, 8.4 miles east of Masontown, on stone abutment of bridge; square	1,767.90
Lenox post-office, at southwest corner of stone foundation; aluminum tablet stamped "2123 GRAFTON"	2,122.318
Lenox, 2.25 miles north of, in southwest corner of stone foundation of Methodist Church; bronze tablet stamped "1851 GRAFTON"	1,850.258
Bruceton Mills, 1.6 miles south of, in southeast corner of cut-stone foundation to residence of Marshall A. Wolfe; bronze tablet stamped "1578 GRAFTON"	1,577.470
Bruceton Mills, in northeast corner of stone foundation to Lutheran Church; aluminum tablet stamped "1549 GRAFTON"	1,549.206
Brandonville, 1.5 miles east of, in southwest corner of cut-stone foundation to residence of Wm. M. Willett; bronze tablet stamped "1831 GRAFTON"	1,831.723
Clifton Mills, on northeast corner of north abutment of iron bridge over Big Sandy Creek; chiseled square	1,535.25

BLACKSVILLE QUADRANGLE.

MORGANTOWN, NORTHWESTWARD TO BLACKSVILLE.

Cassville, 20 feet north of road and 20 feet west of road running north, in stone doorstep of post-office; bronze tablet stamped "999 GRAFTON".	999.202
Core, 2.2 miles north-northwest of, 10 feet south of road, in southeast abutment of bridge over east side of Dolls Run; bronze tablet stamped "913 GRAFTON"	913.265

[a] The closure on this circuit slightly exceeded allowable limit.

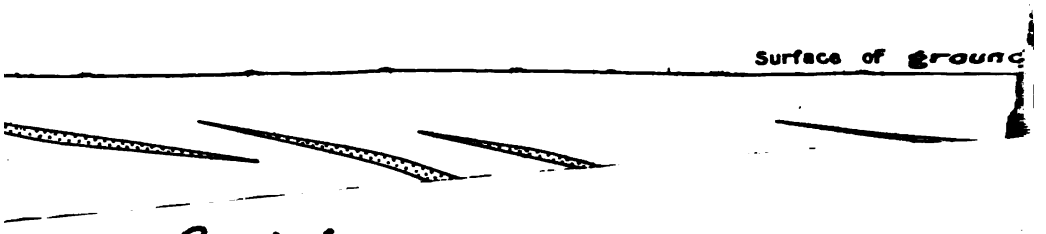
	Feet.
Entress, 1 mile west of, east side of road, north side of Dunkard Creek, on abutment of bridge over, at forks of road; chisel mark	951.11
Blacksville, 10 feet east of center of road, in stone abutment of bridge over Dunkard Creek, 5 feet north of bridge floor; bronze tablet stamped "958 GRAFTON"	957.321
PENTRESS, SOUTH ALONG HIGHWAYS, TO AMOS; THENCE SOUTHEAST ALONG HIGHWAY TO CATAWBA.	
Amos (Fairview), 30 feet from center of road, in doorstep on east side of door to post-office; bronze tablet stamped "1000 GRAFTON"	999.90
Livesville, south side of road, on abutment of iron bridge over Pawpaw Creek, west side of creek; chisel mark	859.65
FAIRMONT, NORTHWEST ALONG BALTIMORE AND OHIO RAILROAD, TO FARMINGTON.	
Barrackville, crossing at station; top of rail	907
Barrackville, 3.7 miles west of, 1.7 miles east of Farmington, on top of northeast abutment of bridge 116; chiseled square	927.69
MANNINGTON QUADRANGLE.[a]	
FARMINGTON, NORTHEAST ALONG BALTIMORE AND OHIO RAILROAD, TO BELLTON.	
Farmington, George Creek Coal and Iron Company's store, at northeast corner in front face of water table; bronze tablet stamped "952 GRAFTON 1901"	951.710
Farmington, 2.8 miles northwest of, on abutment of bridge; chiseled square	953.56
Mannington, corner of Railroad and Market streets, in pillar north of door of Exchange Bank; bronze tablet stamped "975 GRAFTON 1902"	975.391
Metz, at road crossing; top of rail	1,002
Glover Gap, in south foundation of signal tower; bronze tablet stamped "1040 GRAFTON 1902"	1,039.894
Glover Gap, in front of station; top of rail	1,041
Hundred, crossing at station; top of rail	1,019
Hundred, 0.1 mile northwest of, in top of bridge seat of northeast abutment of bridge 128; bronze tablet stamped "1013 GRAFTON 1902"	1,013.276
MANNINGTON, NORTH UP FLAT RUN ALONG PUBLIC ROADS, VIA GALLETIN, TO A POINT NORTH OF CROSSROADS POST-OFFICE (SINGLE SPUR LINE).	
Galletin, 300 feet east of post-office, north of road, in face of rock; bronze tablet stamped "1452 GRAFTON 1902"	1,452.368
Crossroads, 1.6 miles north of post-office, on north side of road down Miracle Run, 30 feet east of Mrs. Marberly's dwelling, in face of large rock; bronze tablet stamped "1014 GRAFTON 1902"	1,014.679

BELINGTON, KINGWOOD, PARSONS, AND THORNTON 15′ (ST. GEORGE 30′) QUADRANGLES.

BARBOUR, PRESTON, RANDOLPH, TAYLOR, AND TUCKER COUNTIES.

Leveling in Thornton quadrangle in 1904 by F. T. Willis and in 1905 by F. T. Willis and George L. Gordon; in Kingwood quadrangle in 1905 by F. T. Willis and R. A. Kiger; and in Belington and Parsons quadrangles in 1905 by F. T. Willis and J. H. Wetzel.

[a] A line was run from Blacksville westward via Brave, Pa., and St. Cloud, W. Va., to Hundred, but no standard bench marks were set.



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